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Nominal plurals in Sign Language of the Netherlands: Accounting for allomorphy and variation

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In both signed and spoken languages, reduplication is a common process in the formation of morphologically complex structures, expressing, e.g., plurality and certain aspectual meanings. A framework in which spoken language reduplication has been formalized frequently is Optimality Theory (OT). While an important attribute of OT-constraints is their universality, to date, the question to what extent such constraints are modality-independent, and thus work for sign language reduplication as well, remains largely unanswered. In the present study, we offer the first OT-formalization of plural reduplication in Sign Language of the Netherlands (NGT). The NGT-data reveal that this language features different plural allomorphs, the choice of which depends on phonological properties of the base noun. However, we also identify variation, e.g., all noun types allow for zero marking.

In our formalization, we aim to introduce constraints that are maximally modality-independent, using constraint types that have previously been proposed for spoken language reduplication. Our formalization is the first to take into account base-reduplicant faithfulness for a sign language, and also the first to account for variation in sign language data by employing stochastic OT, whereby some noise is added to the ranking value of each constraint at evaluation time. Evaluating the modality-(in)dependence of our proposed account suggests that the types of constraints we employ as well as the evaluation in the spirit of stochastic OT are not specific to a modality, while the featural implementation is inevitably modality-dependent.

1 Introduction

Ever since the advent of sign language linguistics in the 1960s, one of the guiding themes has been the question in how far linguistic phenomena at all levels of grammatical description are dependent on the modality of signal transmission, that is, the oral-auditive modality of spoken languages vs. the visual-spatial modality of sign languages. These phenomena include, for instance, the phonological make-up of lexemes, the strategies for building morphologically complex words and signs, and the ways in which these are combined into syntactic structures. By implication, this research agenda raises the question whether theoretical models that have been put forward to account for phonological, morphological, and syntactic structures in spoken languages can also account for sign language structures, that is, in how far these models are modality-independent (Sandler & Lillo-Martin 2006; Quer et al. 2021). In the past 50 years, sign language linguists have contributed significantly towards answering such descriptive and theoretical questions.

In the present study, we offer a contribution to this ongoing debate. The domain of grammar that we are concerned with can be located at the interface between phonology and morphology; the theoretical model that we are going to use is Optimality Theory (OT; Prince & Smolensky 1993 [2004]). As for morphology, it has indeed been claimed that it is, to some extent, characterized by modality-specific properties. Most of the sign languages that have been described to date allow for morphologically complex signs (in particular, verbs). However, in contrast to spoken languages, much of the morphological modifications apply simultaneously, that is, stem-internally (e.g., Aronoff et al. 2005a,b; Sandler & Lillo-Martin 2006; Pfau 2016). These stem-internal changes may affect all phonological building blocks of signs: handshape, location, movement, and also non-manual features (including, for instance, the cheeks and the eyebrows). In contrast, clear cases of sequential affixation are rare across sign languages (Aronoff et al. 2005a,b). A morphological process that involves neither sequential affixation nor stem-internal modification, and that has been shown to be very common across sign languages, is reduplication (e.g., Pfau & Steinbach 2005a; Wilbur 2009) – and it is this particular process which will be the center of our attention.

Across sign languages, reduplication realizes morphological features which are also commonly encoded by that same process in spoken languages (Moravcsik 1978; Rubino 2005), most importantly plurality (e.g., Pizzuto & Corazza 1996; Pfau & Steinbach 2005b) and certain aspect types (e.g., Fischer 1973; Klima & Bellugi 1979; Sandler 1989; Bergman & Dahl 1994; Wilbur 2005). In addition, reduplication has been found to encode reciprocity (Pfau & Steinbach 2003) and intensification and to play a role in the noun-verb distinction (Supalla & Newport 1978) in some sign languages – again, morphological processes that may also be encoded by reduplication in spoken languages, albeit less commonly. The fact that reduplication is common in both modalities is not surprising, given that it can often – though not always (see Downing

& Stiebels 2012 for an overview of iconicity in language) – be considered an iconic process, as the copying of phonological material may reflect a multitude of entities or events of the same type, or, as Dingemanse et al. (2015: 604) put it, “across spoken and signed languages, repetition in word forms is often connected to repetition in their meanings” (see also Kouwenberg & LaCharité 2015).

In the following, we will only be concerned with plural reduplication. As will become clear, this modality-independent process comes with a modality-specific flavor, as the visual-spatial modality allows for reduplication types that are not attested in spoken languages.

OT has been used to account for spoken language reduplication in many studies (for an overview, see Downing & Inkelas 2015), and also for sign language reduplication in two previous studies (Pfau & Steinbach 2003; 2005b, on reciprocals and plurals, respectively). Still, while an important feature of OT-constraints is their universality (Prince & Smolensky [1993] 2004; 1997), it remains unclear to what extent previously proposed constraints can account for both modalities. This paper addresses in how far it is possible for OT-constraints to be modality-independent, and what modality-independence means in this context. Concretely, we offer (i) the first OT-analysis of reduplication in Sign Language of the Netherlands (*Nederlandse Gebarentaal*, NGT), and (ii) the first formalization of sign language variation within stochastic OT. We aim to introduce constraints that are maximally modality-independent, using constraint types that have been proposed for spoken language reduplication. In doing so, we evaluate in how far constraints that have been proposed for the formalization of spoken language reduplication can account for sign language data as well.

We start in Section 2 by summarizing previous research on strategies of nominal pluralization in NGT, the sign language that is the topic of our research. Our OT-analysis of nominal reduplication in NGT is presented in Section 3, where we first address the patterns observed in the corpus and elicited data that our analysis builds on, and then address the issue of variation. In Section 4, we reflect on our formalization, specifically on the question to what extent it is possible to introduce modality-independent OT-constraints, and we also consider how our account fares when it comes to cross-linguistic variation. In this section, we also address some topics for future research. We conclude in Section 5.

2 Nominal pluralization in Sign Language of the Netherlands

A previous study (van Boven 2021) described the nominal pluralization strategies in NGT, based on both data from the Corpus NGT (Crasborn et al. 2008; Crasborn & Zwitserlood 2008) and data elicited by means of a novel elicitation technique, a gap-filling task (for a detailed description of this task, see van Boven 2020). The results obtained by these combined methodologies are different from those reported in previous work on NGT pluralization (Zwitserlood & Nijhof

1999) and, in interesting respects, similar to patterns described for other sign languages, most importantly, German Sign Language (*Deutsche Gebärdensprache*, DGS; Pfau & Steinbach 2005b). Since phonologically triggered allomorphy turned out to play an essential role in NGT pluralization, Section 2.1 introduces the relevant phonological distinctions. Section 2.2 then summarizes the pluralization strategies found in NGT. These results are the basis of the analysis offered in the present study. We give relevant examples of the data in the present article, but also refer to van Boven (2021) for a detailed description. Finally, see Appendix A for an overview of the different nouns included in the data (adapted from van Boven 2021: 355).

2.1 Phonological noun types in NGT

It has been shown that, at the manual level, signs have phonological structure: the identified sublexical building blocks – which can be described in terms of distinctive features – are the handshape, place of articulation, and the movement of the sign (Stokoe 1960; Sandler 1989; for an overview, see Fenlon et al. 2017).

For the present study, only specific movement and location (place of articulation) features are of relevance, since these have been shown to influence the pluralization strategy in NGT (van Boven 2021), as well as a number of other sign languages (Pizzuto & Corazza 1996 for Italian Sign Language; Sutton-Spence & Woll 1999 for British Sign Language; Pfau & Steinbach 2005b for DGS). We follow Pfau & Steinbach (2005b) in distinguishing four different phonological noun types based on these features, all of which are privative: body-anchored nouns, lateral nouns, midsagittal nouns, and complex movement nouns, as summarized in **Figure 1**.[1] Three examples of each noun type are given in **Figures 2–5**.

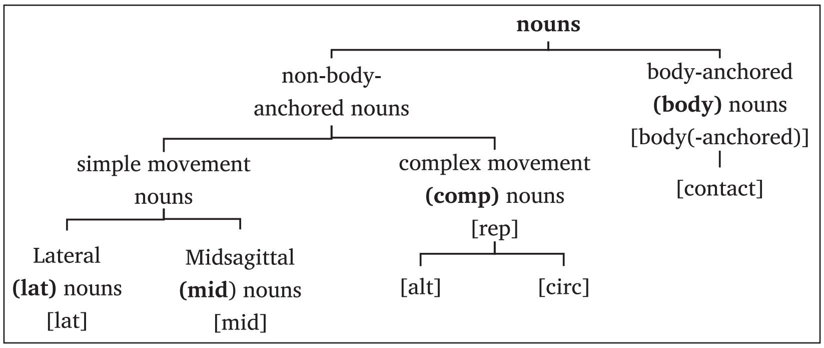


Figure 1: Noun types distinguished for NGT (based on Pfau & Steinbach 2005b: 118) and their feature specifications; the abbreviations for the four main noun types are given in bold in brackets.

[1] Pfau & Steinbach (2005b) use slightly different abbreviations for the different noun types, i.e., B-, L-, M-, and C-nouns; for readability, we adopt the more transparent abbreviations body-, lat-, mid-, and comp-nouns for these phonological noun types.

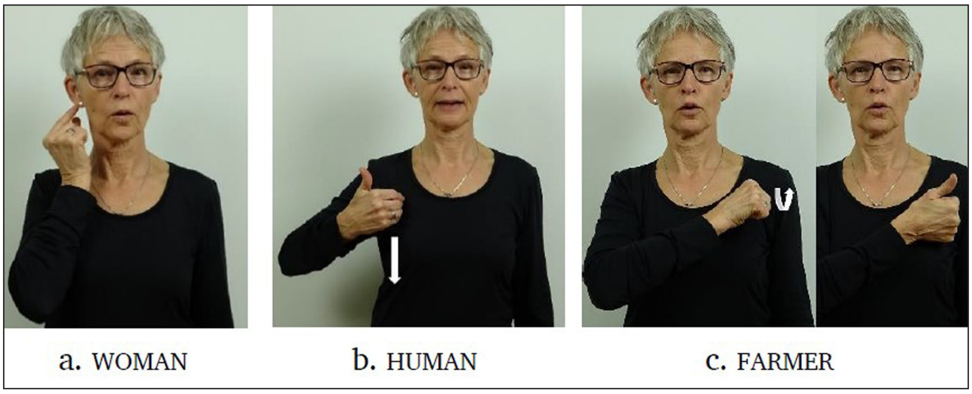


Figure 2: Examples of body-nouns WOMAN (a), HUMAN (b) and FARMER (c) in NGT.

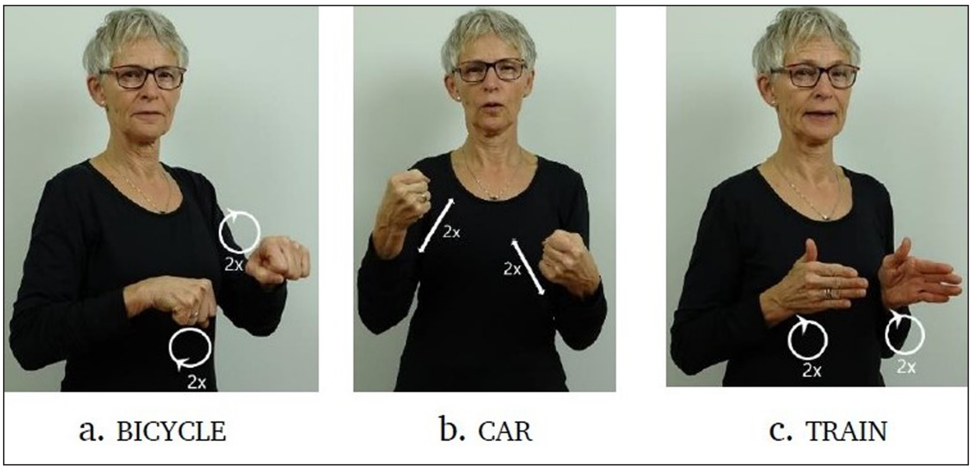


Figure 3: Examples of comp-nouns BICYCLE (a), CAR (b) and TRAIN (c) in NGT.

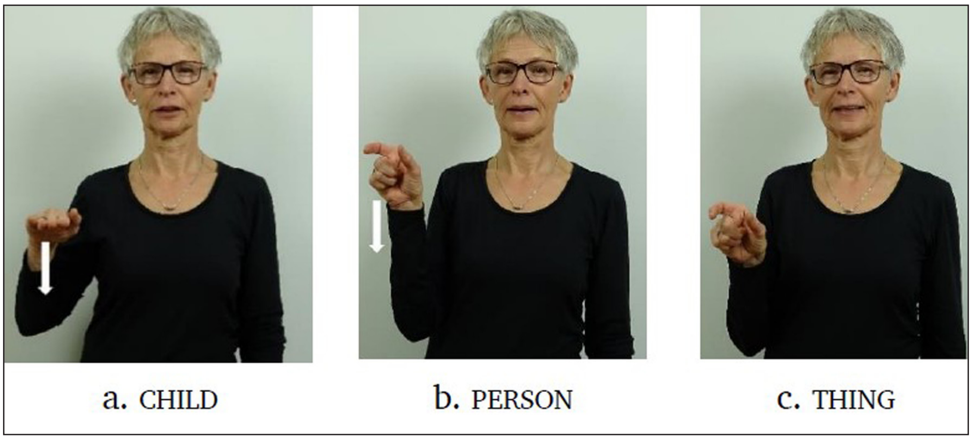


Figure 4: Examples of lat-nouns CHILD (a), PERSON (b) and THING (c) in NGT.

Figure 5: Examples of mid-nouns BOOK (a), CHAIR (b) and TROUSERS (c) in NGT.

The first phonological distinction we make (top of **Figure 1**) is based on place of articulation, and distinguishes nouns that are body-anchored (body) from those that are not. All nouns that have the feature [body] (shorthand for [body-anchored]) are subsumed under body-nouns. The value [body] does not necessarily imply that the noun is articulated on the body; it applies to all nouns that are articulated in clear relation to a specific body part. Body-nouns that actually contact the body are further specified with the feature [contact]. The body-nouns WOMAN (which does not have the feature [contact]), HUMAN, and FARMER (which both do have the feature [contact]) are illustrated for NGT in **Figure 2**.

Then, there are nouns that are not body-anchored. Following Pfau & Steinbach (2005b), we further distinguish these based on movement type: nouns with complex movement and nouns with simple movement. All complex movement (comp) nouns have an inherent repeated movement, i.e., they are lexically specified with the feature [rep]. Additionally, they may have a circular ([circ]) and/or an alternating ([alt]) movement. The NGT noun BICYCLE, illustrated in **Figure 3a**, for instance, is lexically specified for all three movement features and is thus classified as a comp-noun. Other examples of comp-nouns are CAR (**Figure 3b**), which has repeated alternating movement, and TRAIN (**Figure 3c**), which has repeated circular movement.

Simple movement nouns are not specified for inherent repetition in their base form. Within simple movement nouns, we further distinguish midsagittal (mid) nouns from lateral (lat) nouns, the difference being their place of articulation. The place of articulation of lat-nouns is the lateral side of the signing space, i.e., they have the feature [lat]. The lat-nouns CHILD, PERSON, and THING are illustrated in **Figure 4**. Finally, mid-nouns are articulated not on the lateral side, but rather in relation to the midsagittal plane, and thus have the feature [mid]. The mid-nouns BOOK, CHAIR, and TROUSERS are illustrated in **Figure 5**.

Additionally, since signs may be one- or two-handed, we make a distinction that applies across noun types: for all two-handed nouns, we assume a feature [2H], shorthand for [two-handed].

Thus, the nouns BICYCLE, CAR, TRAIN (**Figure 3**), BOOK, CHAIR, and TROUSERS (**Figure 5**) have a feature [2H] to indicate that they are articulated with both hands simultaneously.[2] The nouns WOMAN, HUMAN, FARMER (**Figure 2**), CHILD, PERSON, and THING (**Figure 4**), conversely, have the feature [1H] (for [one-handed]) since they are articulated only with the dominant hand.

The phonological noun types largely influence the choice of pluralization strategy in NGT. The next section discusses this phonologically triggered allomorphy.

2.2 Pluralization strategies in NGT

Several pluralization strategies have been described across sign languages (e.g., Steinbach 2012). One strategy uses the unique possibility of the visual-spatial modality to localize (plural) referents in the signing space, i.e., plural nouns can be localized in the signing space according to their real-life spatial arrangements (the meaning being, for instance 'five cars in a row', see, e.g., Zwitserlood & Nijhof 1999 for NGT; Schlenker & Lamberton 2019 for ASL). Yet, sign languages can also form the 'pure' plural of nouns, that is, the plural form (i.e., 'cars') without conveying information about the spatial distribution of plural entities. In our analysis, we will only be concerned with the latter.

In a previous study into the nominal pluralization strategies in NGT (van Boven 2021), 297 plural nouns extracted from the Corpus NGT and 189 elicited plural nouns were analyzed for morphological plural marking on the base noun, distinguishing the phonological noun types introduced in the previous section.

The Corpus NGT (Crasborn et al. 2008; Crasborn & Zwitserlood 2008) consists of recordings of 92 deaf native NGT signers, both (semi-spontaneous) monologues and dialogues. Part of the data in the corpus has been transcribed by native signers. The transcriptions contain glosses for signs as well as translations. Signs that are – according to the native transcribers – marked for plurality, contain '.PL' in their gloss (for instance, CHILD.PL for 'children'). Plural nouns were

[2] Although this feature applies to all two-handed nouns, we should note that different types of two-handed signs have to be distinguished, but are not all equally represented in our data set. Rather, the vast majority of the two-handed nouns in our data are so-called symmetrical signs, in which both hands move – be it fully symmetrically (e.g., BOOK, Figure 5a) or in alternation (e.g., BICYCLE, Figure 3a) – and are specified for the same handshape ('type 1' signs in Battison 1978; for a more recent account of two-handed signs, and of the constraints on their form first identified by Battison, see Eccarius & Brentari 2007). Yet, in other two-handed signs, only the dominant hand moves while the non-dominant hand serves as place of articulation; in this case, the two hands may have the same handshape ('type 2') or be specified for different handshapes ('type 3'). Our data included one type 2-noun, the mid-noun variant of BOTTLE (N = 2), and two nouns that can be classified as type 3, namely CAFÉ (N = 2) and the mid-noun variant of HOTEL (N = 1). For this reason, we introduce a feature [2H] for all two-handed signs rather than a feature [symmetrical], since the data also includes non-symmetrical two-handed signs.

extracted from the Corpus NGT by searching for .PL on the gloss tiers. Moreover, in order to also take into account potentially zero-marked forms, a search for the plural form of frequent nouns in Dutch was conducted on the translation tier as well. In this way, 297 nouns that had been considered to be plural by native signers were collected. Only plurals that do not denote spatial configuration were included in the data set.

To complement the corpus data, a novel elicitation technique was developed to elicit plural nouns. Five deaf native NGT signers participated. They were presented with sentences in which the plural noun was omitted and replaced by a question mark sign (e.g., a sentence that translates as 'Last October, the QUESTION.MARK were on strike'). Participants were asked to repeat the sentence and fill in the gap based on a picture that shows the targeted plural noun (in this case, an illustration of farmers). Crucially, the spatial configuration of the referents was irrelevant in all sentences. Importantly, these sentences ensure that the nouns are articulated in a plural context. As a double-check, control stimuli elicited the same nouns in singular contexts. This allowed van Boven (2021) to distinguish inherent, i.e., lexically specified, repetition from reduplication, where the latter is only used for pluralization of nouns. For a more elaborate discussion of this task, we refer to van Boven (2020). Further, an English translation of the complete elicitation task, including instructions given to participants, is openly available (van Boven 2023).

The analysis of the corpus data and the elicited data yielded similar results; the pluralization strategies found for each of the four main noun types are summarized in **Table 1** (adapted from van Boven 2021: 335). The subdivision of body-nouns by [contact] and of comp-nouns by [alt] and [circ] turned out to be irrelevant in this data set; see the detailed table in Appendix B. All data annotations for both the corpus and the elicited data are openly available (van Boven 2023).

Table 1 makes clear that no categorical patterns can be extracted from the data – in fact, while there is a correlation between noun type and pluralization strategy, the data also show variation (both within and across signers, and in both data sets). Note that this table does *not* suggest that nouns with similar phonological features have different plural forms, as is for instance the case in spoken German (see the analysis by Trommer 2021); our data do not provide evidence for this type of variation. Rather, in NGT, the same singular form has multiple options for forming its plural: for instance, all mid-nouns such as BOOK, CHAIR or TROUSERS (**Figure 5**) can be pluralized by means of simple or sideward reduplication, or can be left zero-marked.

Noun type	N	Zero marking	Simple reduplication	Sideward reduplication	Simultaneous articulation	Simultaneous sideward reduplication
body	185	40.2%	55.7%	3.2%	1.1%[a]	0%
comp	40	57.5%	37.5%	5%	0%	0%
lat	224	15.6%	1.8%	67.9%	1.8%	12.9%
mid[b]	37	43.2%	29.7%	21.6%	0%	0%

Table 1 Pluralization strategies per phonological noun type in NGT; shaded cells indicate most frequent strategies (adapted from van Boven 2021: 335).
[a] This 1.1% comprises two instances of simultaneous articulation: both concern the body-noun PROBLEM, articulated by one signer in the corpus, within only three seconds. In both cases, PROBLEM is followed by the two-handed noun CRISIS (once directly, and once separated by a pointing sign and a two-handed palms-up sign). Since CRISIS has the same handshape as PROBLEM, this simultaneous articulation may well be the result of assimilation to the following two-handed sign.
[b] The attentive reader will have noticed that the percentages for the mid-nouns in the last row do not add up to 100%. The reason for this is that two mid-noun tokens in our data set undergo strategies that occurred only once: One signer articulates BOOK (5a) without repetition, but with the hands moving further apart from one another than in its base form, indicating plurality, and another signer articulates CHAIR (Figure 5b) at different locations in space, but with one, fluent movement – not with repetitive movements. We ignore these exceptional strategies, and they were therefore not included in the table.

We first discuss the most frequent patterns, i.e., the shaded cells in **Table 1** (see also van Boven 2021). The shaded cells in **Table 1** indicate four frequently occurring pluralization strategies in NGT: (i) zero marking, (ii) simple reduplication, (iii) sideward reduplication, and (iv) simultaneous sideward reduplication. We assume that these strategies are indeed employed to realize pluralization, given the nature of the data: they occur in contexts that are interpreted as plural by native signers (for the corpus data) or are used to distinguish plural nouns from singular nouns (in the elicited data). As for zero marking, additional evidence comes from the fact that zero-marked nouns co-occur with other elements that are overtly marked for plurality, as in (1a) and (1b). In (1a), the zero-marked nouns TROUSERS is followed by the verb TRY.ON, which is marked for plurality by means of reduplication. In (1b), the zero-marked noun SHOP is followed by a sideward reduplication of INSIDE, to indicate that the signer went into multiple shops. Similarly, zero-marked nouns sometimes co-occur with indexical signs with an arc-shaped movement, which refer to plural entities as in (1c). Still, often only the context makes clear that the noun should be interpreted as plural rather than singular, as in (1d) and (1e). Zero marking occurs with all noun types – that is, reduplication is not obligatory for any of the noun types.

(1) a. INDEX$_1$ MANY **TROUSERS** TRY.ON+ + +
‘I tried on many [pairs of] trousers.’ ([p02]; van Boven 2021: 345)

b. **SHOP** INSIDE> + > + > +
‘in shops’ (van Boven 2021: 345)

c. **GIRL** INDEX$_{arc}$ MOSTLY HAVE BRACELET NECKLACE
‘Girls often wear a bracelet and a necklace.’ [p06]

d. AMSTERDAM NICE **SHOP** PRESENT
‘There are nice shops in Amsterdam.’ [p04]

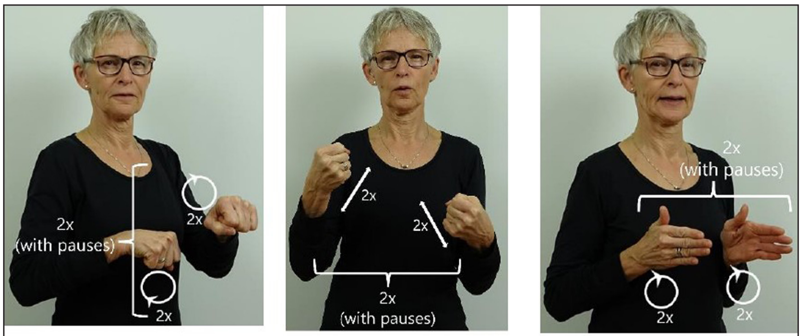
e. […] INDEX$_{3a}$ SELF PSYCHOLOGY **PROBLEM** […]
‘[The child] could develop psychological problems.’
([CNGT0132; 03:06.040]; van Boven 2021: 340)

Yet when there is plural marking, the choice between the different reduplication types largely depends on the phonological properties of the base nouns, i.e., on the noun types we introduced above.

Both body-nouns (see **Figure 2**) and comp-nouns (see **Figure 3**) usually undergo simple reduplication, whereby the noun is repeated at one location. Simple reduplication of the body-nouns WOMAN, HUMAN and FARMER is illustrated in **Figures 6a-c**, and simple reduplication of the comp-nouns BICYCLE, CAR, and TRAIN is illustrated in **Figures 7a-c**. For the sake of clarity and for privacy reasons, nouns that were either extracted from the corpus or elicited have been reproduced by a native signer. We gloss simple reduplication by adding pluses to the gloss of the sign; the number of pluses indicates the number of repetitions – thus, if a sign is repeated twice, this means that there are three movement cycles (e.g., WOMAN in **Figure 6a** has a movement in its base, and a movement in each of the reduplicants). This is noted by a gloss of the base noun and two pluses; in other words, the number of pluses reflects the number of reduplicants.

a. WOMAN+ + b. HUMAN+ + c. FARMER+ +

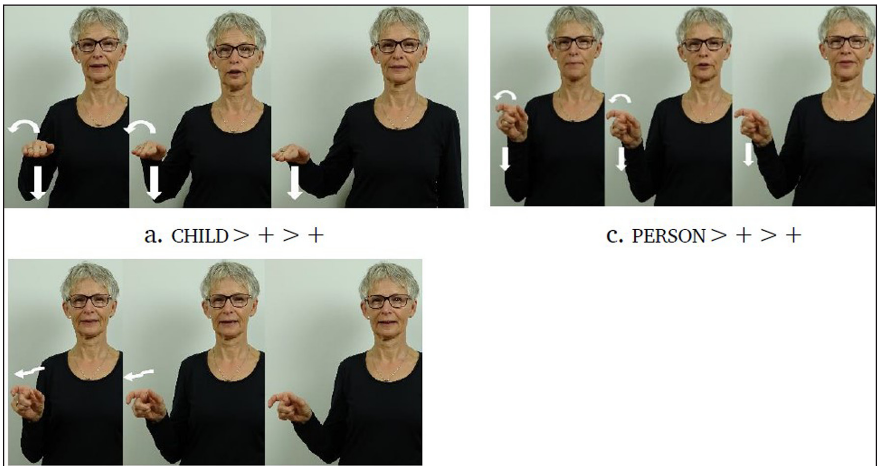
Figure 6: Simple reduplication of body-nouns WOMAN (a), HUMAN (b), and FARMER (c) (all signs reproduced by a native signer).



a. BICYCLE + b. CAR + c. TRAIN +

Figure 7: Simple reduplication of comp-nouns BICYCLE (a), CAR (b), and TRAIN (c) in NGT (all signs reproduced by a native signer).

Unlike body- and comp-nouns, lat-nouns (e.g., CHILD, PERSON, and THING in **Figure 4**) normally undergo sideward reduplication, illustrated in **Figure 8**, whereby the noun is repeated while moving the hand sideward. For this noun type, sideward reduplication sometimes combines with simultaneous articulation, illustrated in **Figure 9**, where a one-handed base-noun is articulated with two hands. Note that under simultaneous sideward reduplication, the two hands move in opposite directions.[3] Sideward reduplication is glossed by adding >+ to the noun gloss; again, the number of pluses (and arrows) reflects the number of repetitions/reduplicants (e.g., adding two repetitions to CHILD results in three movement cycles, as shown in **Figure 8a** – this is reflected by two arrows and pluses; one for each repetition/reduplicant). Simultaneous articulation is glossed by the subscript 2H (i.e., two-handed).



a. CHILD > + > +

b. THING > + > +

c. PERSON > + > +

Figure 8: Sideward reduplication of lat-nouns CHILD (a), THING (b), and PERSON (c) in NGT (all signs reproduced by a native signer).

[3] Note that under simultaneous sideward reduplication of lat-noun PERSON, the hands move alternately rather than in parallel, as shown in Figure 9c – we come back to this in our discussion, Section 4.3.

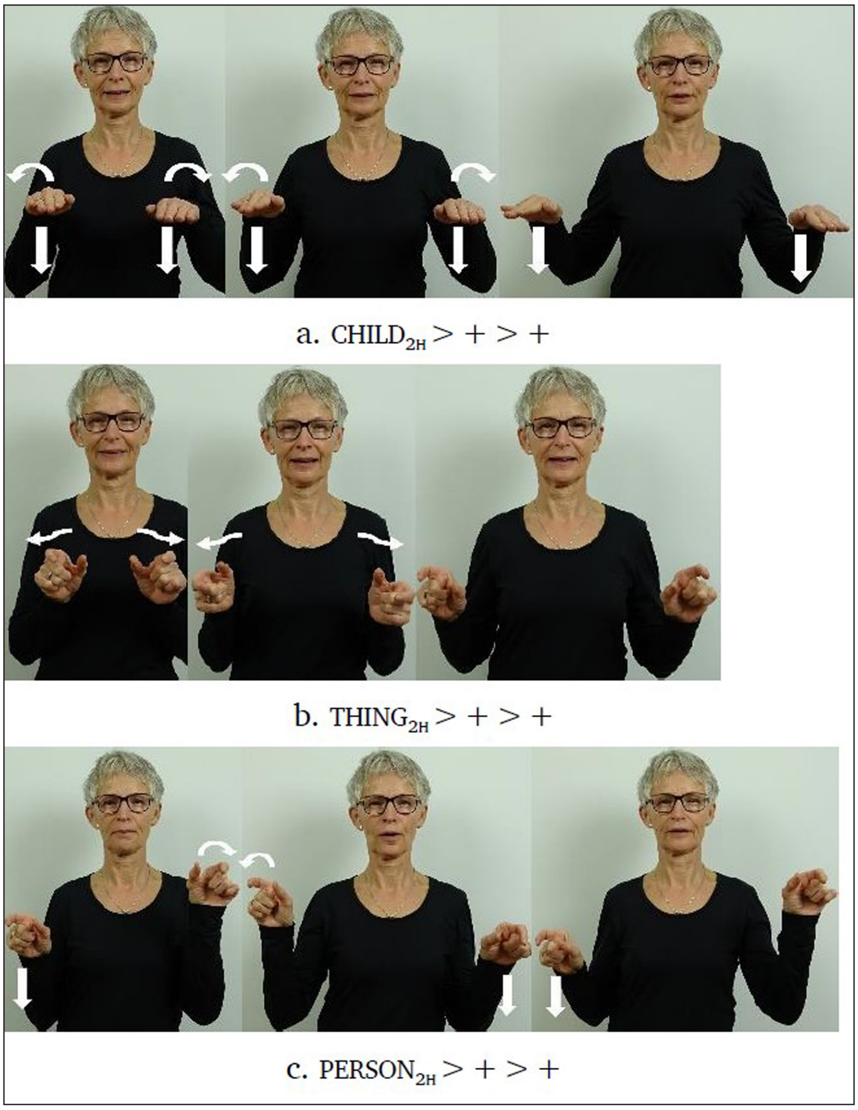


Figure 9: Simultaneous sideward reduplication of lat-nouns CHILD (a), THING (b), and PERSON (c) in NGT (all signs reproduced by a native signer).

Note that, for obvious reasons, simultaneous articulation can only occur when the base noun is one-handed. Our data set did not contain any one-handed mid- or comp-nouns, and thus it would have been impossible for this strategy to co-occur with these noun types.[4]

[4] While one-handed comp-nouns exist in NGT (e.g., SIREN), but were simply not included in our data set, we suspect that there are no one-handed mid-nouns in NGT. One-handed nouns articulated on the midsagittal plane are also body-anchored (e.g., APPLE), and are therefore specified as body-nouns in our classification.

A reviewer speculates that the sideward movement observed in the reduplication of lat-nouns might not be motivated by phonological constraints alone. Phonological features of signs sometimes have a semantic motivation (Stokoe 1991; van der Kooij 2002; Sandler 2018), that is, the sublexical building blocks may reflect semantic properties of the referent in iconic signs (e.g., in BICYCLE in **Figure 3a**, the handshape and movement reflect the pedals of a bike). If the lat-noun CHILD was reduplicated without sideward movement, the resulting form could potentially be misinterpreted as a repeated action (i.e., an iconic representation of bouncing a ball). This is an interesting suggestion, and it motivated us to check for all lat-nouns in our data set whether simple reduplication could potentially give rise to such a misinterpretation. Yet, while this might hold for some of our lat-nouns (e.g., LAMP in **Figure 10**, where simple reduplication could be interpreted as 'flashing light'), for others (such as PERSON (**Figure 4b**), WEEK, THING (**Figure 4c**) and BOTTLE), it seems highly unlikely that repeating the sign in one location could lead to a misinterpretation as a repeated action.

LAMP

Figure 10: Lat-noun LAMP in NGT (Klomp 2021: 156; © Ulrika Klomp, reprinted with permission).

Another argument against a semantic explanation for sideward reduplication is that this misinterpretation could also happen with noun types that do undergo simple reduplication in NGT, such as comp-nouns. Consider the comp-noun BICYCLE, where simple reduplication (**Figure 7a**) could also be taken to mean 'to bike again and again', given the fact that the NGT verb BIKE has the same form as the noun (in fact, reduplication also functions as an aspect marker in NGT, cf. Hoiting & Slobin 2001; Oomen 2016; van Boven & Oomen 2021; van Boven accepted). Still, no sideward movement is added to avoid the potential confusion. A similar situation may arise in spoken languages, when the plural form of a noun happens to be homophonous to a verbal meaning. In German, for instance, such homophonous nominal and verbal meanings may not even be related to each other: e.g., [bakŋ̍] ‘cheeks’ or ‘to bake’, [bʁa͡ʊən] ‘eye brows’ or ‘to brew’, [ʋɛkŋ̍] ‘bread rolls’ (regional variant) or ‘to wake up’. Given these facts, we conclude that the sideward movement in NGT nouns is indeed added for phonological rather than semantic reasons.

Finally, **Table 1** shows that mid-nouns (e.g., BOOK, CHAIR, and TROUSERS in **Figure 5**) sometimes undergo simple reduplication, illustrated in **Figure 11**, and sometimes sideward reduplication, (with comparable percentages, see **Table 1**), as illustrated in **Figure 12**.

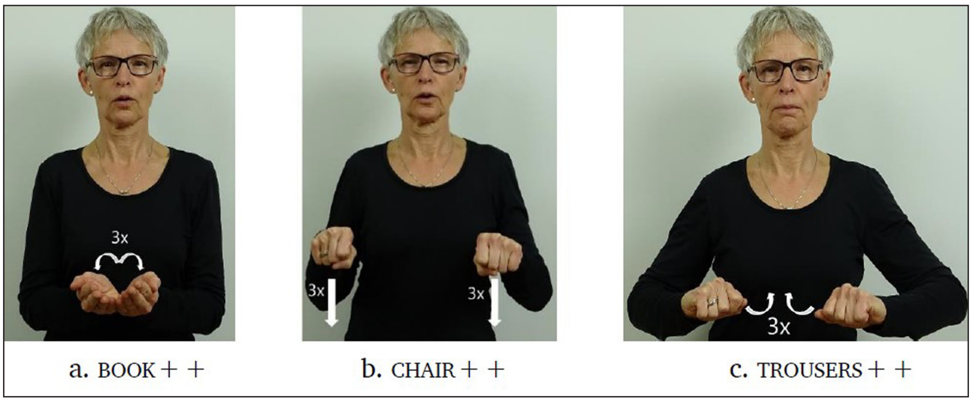


Figure 11: Simple reduplication of mid-nouns BOOK (a), CHAIR (b) and TROUSERS (c) in NGT (all signs reproduced by a native signer).

Up until now, we have ignored the instances of simple and sideward reduplication and of simultaneous articulation that occurred in 5% or less of the cases for a specific noun type. These instances show that there is quite some variation in the data set, and that the patterns that we describe above are not completely categorical. For instance, while comp-nouns for the largest part undergo simple reduplication or are zero-marked, a small percentage actually undergoes sideward reduplication. Also, all noun types alternate between reduplication and zero marking: compare, for instance, zero-marked TROUSERS in (1a) to simple (**Figure 11c**) and sideward (**Figure 12c**) reduplication of the same noun. Finally, we have not yet addressed the strategy of simultaneous articulation, which only occurs with a very small percentage of lat-nouns and possibly body-nouns (see **Table 1**). Simultaneous articulation involves articulating a one-handed noun with two hands, without additional repetition, as shown in **Figure 13** for lat-nouns CHILD and THING. We do consider this a special type of reduplication.

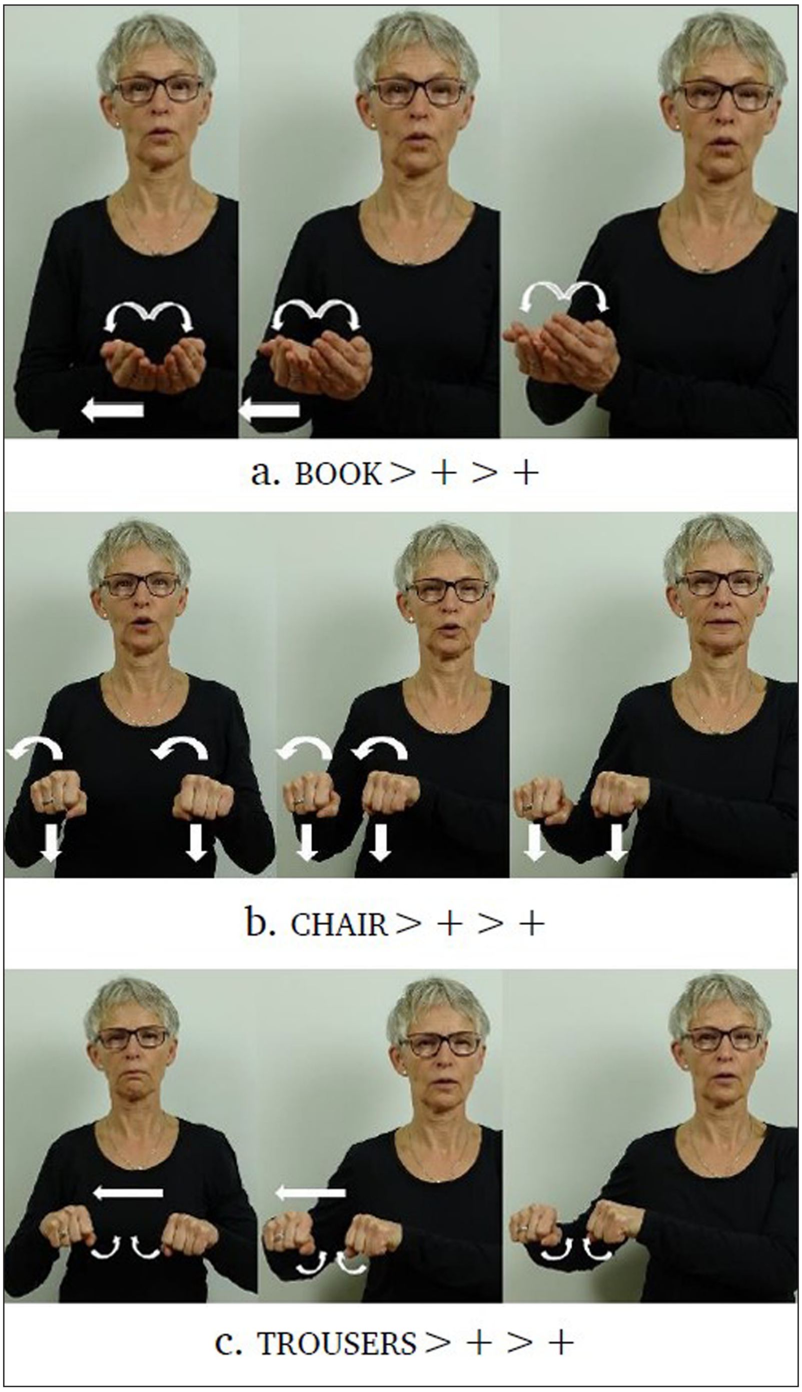


Figure 12: Sideward reduplication of mid-nouns BOOK (a), CHAIR (b) and TROUSERS (c) in NGT (all signs reproduced by a native signer).

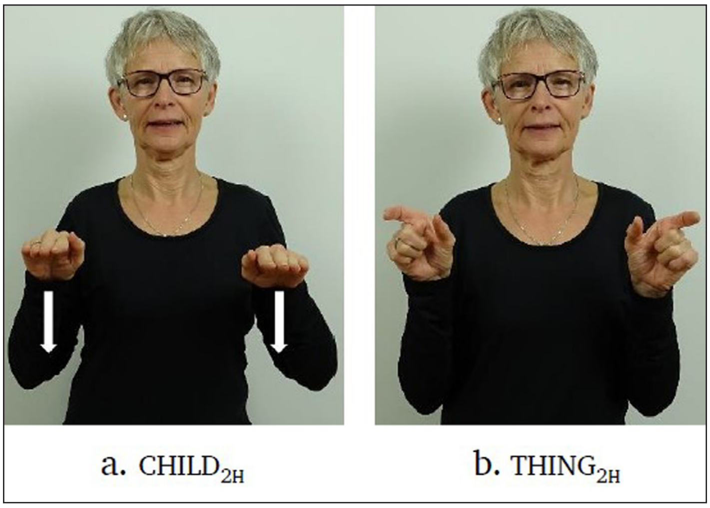


Figure 13: Simultaneous articulation of lat-nouns CHILD (a) and THING (b) in NGT (both signs reproduced by a native signer).

Phonologically triggered allomorphy in plural marking has previously been described for other sign languages as well, although the exact restrictions differ per language. Pfau & Steinbach (2005b) observe that DGS lat-nouns undergo sideward reduplication, while DGS mid-nouns undergo simple reduplication – other strategies are claimed to be ungrammatical for these noun types. Comp-nouns and body-nouns cannot undergo reduplication in DGS, but are always zero-marked. An additional strategy has been described for other sign languages, namely simultaneous reduplication, whereby a one-handed noun is not only repeated, but also articulated with two hands. While this strategy has not been described for DGS, it has previously been noted by Wilbur (1987) for American Sign Language (ASL) and by Skant et al. (2002) for Austrian Sign Language (in both sign languages, simultaneous reduplication involves an alternating movement – see also footnote 3 and Section 4.3). Simultaneous reduplication has also been described for NGT by Harder et al. (2003), who found that one-handed base signs were sometimes articulated with two hands. As discussed, our data only presented us with simultaneous sideward reduplication (i.e., repetition combined with sideward movement, see **Figure 9**) and simultaneous articulation (i.e., two-handed articulation without repetition or sideward movement, see **Figure 13**) – but the latter only extremely infrequently.

2.3 Modality-specific patterns

Besides offering a description and a formal account of the NGT pluralization patterns, another goal of the present study is to evaluate the modality-independence of the OT-formalization of the attested patterns. In this section, we briefly address modality-independent and modality-specific characteristics of pluralization, while our formalization, in particular the universality of the constraints we use, will be evaluated in Section 4.1.

An aspect that is clearly modality-independent is the use of reduplication as a pluralization strategy. This is not surprising, as the copying of phonological material provides the language user with iconic means to signal a multitude of entities of the same type. The change of a phonological feature, as observed in sideward reduplication, can be likened to cases of non-faithful reduplication, i.e., base-reduplicant non-identity, which are common across spoken languages. Besides that, phonologically triggered plural allomorphy is also attested in spoken languages, English plurals being an example. Finally, variation of the type observed in the NGT data (i.e., different reduplication strategies and zero marking applying to one and the same noun) may be uncommon in spoken languages, but it is attested, as we will show in Section 3.3.

Turning now to aspects that are modality-specific, it first has to be acknowledged that the phonological features that are responsible for allomorphy – that is, location features like [lat] or [mid] and movement features like [alt] and [circ] – are specific to the visual-spatial modality. This may seem trivial: of course, spoken languages do not employ features like [alt], while features like [voiced] cannot play any role in sign languages. Yet, this obvious fact will have repercussions on the constraints we employ in the next section. Further modality-specific characteristics emerge when we zoom in on the reduplication strategies. Simple reduplication is modality-independent. Sideward reduplication, on the other hand, combines modality-independent and -specific features: as mentioned before, non-identity between base and reduplicant is also observed in spoken languages; what makes sideward reduplication special is that this non-identity involves movement in space and, consequently, a change in location (rather than, e.g., a change in vowel height). The strategies that are most clearly modality-specific are those that involve the simultaneous addition of a second articulator, the non-dominant hand (see **Figures 9** and **13**). Given the constraints imposed by the vocal apparatus, no comparable strategy is available in spoken languages.

3 OT-analysis of nominal reduplication in NGT

This section presents our OT-formalization of the nominal pluralization strategies observed in NGT. No previous OT-formalization of NGT plural reduplication exists, but there is one for another sign language, namely DGS, which was proposed by Pfau & Steinbach (2005b). However, the constraints used in their formalization largely involve modality-specific concepts, and little parallels are drawn to spoken language formalizations. For instance, they propose a constraint *MOVE, which is clearly modality-specific, and they do not include base-reduplicant faithfulness – a concept which has proven useful for spoken languages. Moreover, Pfau & Steinbach (2005b) do not formalize any variation. We will get back to this in more detail in Section 4.1.

In our formalization, however, we aim to include constraints that are as modality-independent as possible, given the premise that OT-constraints are universal. As such, we employ constraint types that have previously been proposed for spoken language reduplication. This is visible in several aspects of our analysis, as it i) distinguishes between IO-FAITH and BR-FAITH constraints,

ii) employs an ALIGNMENT constraint that punishes the non-simultaneous realization of a plural morpheme and the noun stem, and iii) relies on a systematic implementation of the relevant phonological features of the base noun. We also employ stochastic OT to account for the variation observed in our data, as was also done for spoken languages, but never for a sign language.

In Section 3.1, we define a morphological constraint that requires plural realization in the form of reduplication of the noun sign, a constraint that requires the reduplicant plural morpheme to be a syllable, and a general ALIGNMENT constraint. Section 3.2 then illustrates how the attested reduplication strategies emerge. Finally, Section 3.3 provides the ranking values that can account for the optionality and variation we observed in our data.

3.1 Implementing the plural morpheme

We observed multiple ways for realizing the plural in NGT: three frequent types of reduplication, one marginal one, and zero marking. The three frequent reduplication types were (i) simple reduplication by repetition of the base noun, (ii) sideward reduplication, imposing a sideward movement on the reduplicated form, and (iii) simultaneous sideward reduplication with an additional articulation of the second hand for one-handed signs. The marginal one was reduplication by additional articulation with the second hand, which we call simultaneous articulation. We therefore assume that reduplication of the noun is the default strategy for implementing the plural in NGT, while the type of reduplication (simple, sideward, simultaneous sideward, or simultaneous articulation) results from noun-specific phonological features and a requirement on the form of the reduplicant.

Since reduplication is the phonological realization of pluralization, and in order to evaluate the input-output faithfulness of the reduplicant, we employ a MAX constraint as formulated in (2):

(2) MAX-RED$_{PL}$: Assign a violation mark if the reduplicant plural morpheme has no correspondent in the output.

The phonological make-up of signs allows for multiple morphological modifications to apply at the same time – for instance, changing the begin- and endpoints of the sign in verbal agreement, or adapting the handshape in classifier constructions (Pfau & Glück 2000; Aronoff et al. 2005b; Meir 2012). In other words, as we mentioned already in the Introduction, sign languages often apply morphological modifications simultaneously, i.e., in stem-internal position (e.g., Aronoff et al. 2005a,b; Sandler & Lillo-Martin 2006; Pfau 2016). In NGT pluralization, this is also the case in the simultaneous articulation that we observed, where all features of a one-handed base are copied onto the second, non-dominant hand, and as a result the one-handed sign is articulated as a symmetric two-handed sign. Yet, in our data, this reduplication strategy only occurred marginally: we had four instances of lat-nouns that underwent simultaneous articulation.[5] Our

[5] In addition, Table 1 also indicates that two body-nouns underwent simultaneous articulation, but as explained in footnote a with this table, these were likely instances of assimilation rather than pluralization.

data did not include any one-handed mid- or comp-nouns that would allow for simultaneous articulation. A previous study on NGT (Harder et al. 2003) found that simultaneous articulation is used in pluralization, in particular when the meaning to be expressed is 'two'.[6] We conclude that, although simultaneous articulation is a marginally occurring strategy of plural reduplication in NGT, it nevertheless needs to be accounted for.

Spoken languages also allow for the simultaneous realization of morphemes, for instance with morphological tones or by means of vowel fronting (umlaut), though this type of morphological modification is far less common than in sign languages. In fact, it is articulatorily impossible for a reduplicant to be articulated completely simultaneously with its stem in a spoken language. Still, some cases come close. For instance, Riggle (2006) analyzes reduplication in Pima (which marks the plural on nouns, adjectives, adverbs, verbs, and some determiners) as infixation: the reduplicant follows the first vowel of the stem (e.g., /hó.d̪ai/ 'rock' – /hó.**ho**.d̪ai/ 'rocks', p. 858). This infixation is formalized with an Alignment constraint (in combination with an Anchor constraint), which requires the left edge of the reduplicant to occur as close as possible to the left edge of the word (Riggle 2006: 872). Wiese (2009) introduces a similar constraint for schwa insertion in nominal pluralization in German – although this does not involve reduplication. For schwa insertion in a stem, Wiese (2009: 151) proposes a right-alignment constraint: the right edge of a stem is aligned with the right edge of its phonological word, from which it follows that German /zeː.gəl/ 'sail' is preferred over */zeː.glə/ in both its singular and plural form.

Since in sign languages it is actually possible to align base and reduplicant, they generally seem to be more apt to satisfy these so-called Alignment constraints that have been introduced for spoken languages (see McCarthy & Prince 1993a).[7] An Alignment constraint relevant for our present analysis is given in (3), requiring the plural morpheme to align with the left edge of the stem.

(3) Align (Stem, L, Plural, L), short Plural-L:
Assign a violation mark for every instance of the reduplicant plural morpheme that is not aligned with the left edge of a stem.

6 This dual interpretation of simultaneous articulation was also found for British Sign Language (Sutton-Spence & Woll 1999). Of the four instances of lat-nouns that underwent simultaneous articulation in our data, only one had the meaning 'two'.

7 McCarthy & Prince (1993a: 2) define Alignment constraints as referring to prosodic and/or grammatical (morphological or syntactic) categories. As their examples on p. 3 show, these constraints can be used in multiple ways: (i) to map morphological categories onto prosodic ones, hence as constraints on the morphology-phonology interface, (ii) to align two types of prosodic categories such as, e.g., the foot and the prosodic word in stress assignment, hence as purely phonological constraints, and (iii) to map morphological categories onto each other, e.g., stem and affixes, hence as morphological constraints. In the present article, we employ possibility (i). With this, we use constraints of the morphology-phonology interface, such as this Alignment constraint, together with purely phonological constraints, such as Input-Output-Ident constraints that compare phonological underlying to phonological surface forms, in one mapping. A stricter analysis would involve two separate mappings for this, see, e.g., Boersma & van Leussen (2017) for an example.

This constraint is not violated if the plural is not implemented. PLURAL-L is also not violated if the reduplicant plural morpheme is realized by simultaneous articulation. It is violated, however, when reduplicants are added to the stem in a sequential order.

What the non-simultaneously articulated reduplication types all have in common is that the reduplicant introduces a separate syllable. Let us briefly elaborate on the notion of syllable. In sign language phonology, it is commonly assumed that syllables consist of locations and movements – be they a hand-internal movement (e.g., handshape change) and/or a path movement – and that the movement component constitutes the syllable nucleus (e.g., Perlmutter 1992; Sandler 2008; Jantunen & Takkinen 2010). Crucially, only sequential movements create syllables; that is, a sign like BOOK (**Figure 5a**), in which both hands simultaneously perform a movement, is monosyllabic. A tendency that has been observed across sign languages is the so-called "monosyllable conspiracy" (Sandler 1999; 2008): words in sign languages tend to be monosyllabic, in spite of their morphological structure. For instance, in ASL, some compounds of two signs are reduced to only one movement, i.e., one syllable (Sandler 1999; 2008; Sandler & Lillo-Martin 2006). Reduplication is striking in this respect, since it actually adds movements, and thus syllables. Still, reduplication in ASL is taken as evidence for the sign language syllable, since under aspectual inflection, only one syllable is reduplicated. For instance, in ASL, BLOW-TOP 'to explode with anger' is a compound that still has two syllables, and when it is inflected for habitual aspect, only the final syllable is reduplicated. For monosyllabic verbs, there is complete reduplication in ASL (Sandler 1989; 2008). Similarly, in NGT, when the nouns under investigation are reduplicated, the reduplicant always contains one movement; thus, in sequential reduplication, a syllable is added with each reduplicant.[8] In contrast, pluralization by means of a simultaneous two-handed articulation of an underlyingly one-handed sign (e.g., CHILD; see **Figure 13**) does not involve the addition of a separate syllable.

In several spoken languages, too, the syllable is the unit that is reduplicated. For example, Gouskova (2007) shows for Tonkowa that there is a templatic requirement on the reduplicative prefix: it is limited to a single light syllable (CV-structure), something that is otherwise marked in the language. The reason that only the light syllable is copied, is because of the templatic cover constraint RED $= \sigma_{\mu}$ "The reduplicative morpheme is a light syllable" (Gouskova 2007: 375).

We postulate that the plural reduplicant in NGT, too, ideally is a separate syllable, expressed with the fairly high-ranked, size-defining constraint in (4) (see also McCarthy & Prince 1993b; Downing 2006: 13; Downing & Inkelas 2015: 518).

[8] Although not annotated systematically, in some cases of sideward reduplication, the individual movement of each reduplicant was difficult to discern. For instance, for the lat-noun CHILD, we noted that in fast signing, some signers reduced the movement repetition considerably, sometimes to the extent that the downward movement of the base was followed by a single sideward movement. We analyzed this as a case of phonetic reduction and not as a separate pluralization strategy, and still assumed that each reduplicant has its own movement in the phonological surface form.

(4) Red$_{PL}$ = σ: Assign a violation mark if a correspondent of the reduplicant plural morpheme is present in the output but is not a syllable.

The workings of these three constraints and the notations used in the present formalization are illustrated in **Tableau 1**. Input to this and all following tableaux are the noun and the reduplicant plural morpheme Red$_{PL}$, where the latter does not have any underlying features but requires a copy of the features of the noun-stem in the output. Rather than providing the complete phonological feature bundle for the input noun stems, we specify only the following information: (i) their place of articulation with one of the privative features [lat, mid, body] to distinguish lat-, mid-, and body-nouns, (ii) a feature [rep] in the case of comp-nouns, and (iii) whether a sign is one-handed [1H] or two-handed [2H]. Features of type (i) and (ii) are sufficient to distinguish between the noun types we introduced in Section 2.1; the third type, one- or two-handedness, will be shown to also be of relevance in accounting for their choice of pluralization allomorphs. Output candidates contain again only realizations of these relevant features, both in the base and in the possible reduplicant.

	human + Red$_{PL}$ $\begin{bmatrix}\text{1H}\\\text{body}\end{bmatrix}$	Max-Red$_{PL}$	Red$_{PL}$ = σ	Plural-L	Ident-BR-Place	Ident-IO-[1H]
a)	$\begin{bmatrix}\text{1H}\\\text{body}\end{bmatrix}$	*!				
☞ b)	$\begin{bmatrix}\text{1H}\\\text{body}\end{bmatrix}$ $\begin{bmatrix}\text{1H}\\\text{body}\end{bmatrix}$			*		
c)	$\begin{bmatrix}\text{1H}\\\text{body}\end{bmatrix}$ $\begin{bmatrix}\text{1H}\\\text{lat}\end{bmatrix}$			*	*!	
d)	$\begin{bmatrix}\text{2H}\\\text{body}\end{bmatrix}$		*!			*

Tableau 1: OT-formalization of pluralization in NGT, with one-handed body-noun human.

Tableau 1 has as input the one-handed body-noun human. Candidate a) corresponds to the strategy of zero marking (as it only has one feature bundle, corresponding to the base), and thus violates the constraint Max-Red$_{PL}$ introduced in (2). Candidate b) has a faithful reduplicant of the stem (the second feature bundle, with the same features as provided in the input), and corresponds to the strategy of simple reduplication. Candidate c) involves an unfaithful reduplicant with a change in location from [body] to [lat]: the feature [lat] requires that the reduplicant is articulated at a location lateral to the place of articulation of the base, as explained in the following section. This candidate therefore represents the strategy of sideward reduplication. Both candidates b) and c) have a correspondence to the underlying Red$_{PL}$: the reduplicant occurs as separate syllable sequentially,[9] and therefore both candidates satisfy Red$_{PL}$ = σ but violate Plural-L. The zero-

[9] We assume that the base sign precedes the reduplicant, and that signers therefore do not recognize the plural form at the start of the base sign, before the reduplicant is articulated.

marked candidate a), on the other hand, does not involve sequential morphological processes and consequently violates neither PLURAL-L nor $\text{RED}_{\text{PL}} = \sigma$, though it violates MAX-RED_{PL}.

Candidate c) is an output form where the base is articulated on the body, while the reduplicant has a lateral location feature (i.e., sideward reduplication of a body-anchored noun). In other words, there is a difference in location features between base and reduplicant. Correspondence between base and reduplicant has proven useful in many OT-accounts of spoken languages, comparing the phonological form of the reduplicant, which may be a complete or a partial copy of the base, to the form of the base (Base-reduplicant correspondence theory; McCarthy & Prince 1993b et seq.). When base and reduplicant are non-identical, i.e., in so-called complex reduplication, in spoken languages the vowels or consonants can be changed or added, or the phoneme order can be reversed (Rubino 2005). The similarity between the base form and its reduplicant is evaluated in OT with so-called Base-Reduplicant Faithfulness Constraints (McCarthy & Prince 1999; henceforth: BR-FAITH). BR-FAITH is relevant for our NGT data, too, since in sideward reduplication of certain nouns (as in candidate c) in **Tableau 1**), there are different location features in the base and the reduplicant. We thus introduce the base-reduplicant faithfulness constraint IDENT-BR-PLACE defined in (5).[10]

(5) IDENT-BR-PLACE: Assign a violation for an incongruency in place of articulation between base and reduplicant.

Candidate d) is a form in which the features of the underlyingly one-handed sign are copied onto the non-dominant hand, and thus represents the reduplication strategy of simultaneous articulation. This candidate violates the constraint $\text{RED}_{\text{PL}} = \sigma$, because the reduplicant does not consist of a syllable. Also, while the input form is a one-handed sign [1H], the output candidate d) is a two-handed sign [2H]. Here, we observe a difference between input and output. Input-Output Faithfulness (IO-FAITH(FULNESS)) constraints are, of course, a crucial component of any OT formalization. Output candidate d) in **Tableau 1** violates IDENT-IO-[1H] as defined in (6), due to its change in handedness:

(6) IDENT-IO-[1H]: Assign a violation for change in one-handedness between input and output.

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[10] Independent evidence for the importance of the location feature [body-anchored] comes from the domain of verbal agreement. Agreement marking in NGT (just as in other sign languages) involves the spatial modification of verbs, such that their begin/end points align with the loci associated with subject/object referents. However, body-anchored verbs cannot be modified spatially to mark agreement, as this would imply changing a lexically specified location feature (Zwitserlood & van Gijn 2006). Moreover, since body-anchoredness often has an iconic motivation (e.g., Meir et al. 2007; Oomen 2017), one might consider to also invoke constraints related to iconicity (see, e.g., Eccarius 2011 for iconic handshapes). However, since not all body-anchored nouns in NGT have a clear iconic motivation, such constraints would not generalize over all body-anchored nouns. Therefore, we use the more general constraint IDENT-BR-PLACE instead.

In **Tableau 1**, MAX-RED$_{PL}$ and RED$_{PL}$ $= \sigma$ are highest ranked, though their actual ranking and that of all other constraints to account for all the variation that we found in our data will be determined in Section 3.3.

3.2 The choice of reduplication strategy

As has been shown in Section 2.2, body-, comp-, and mid-nouns can all be pluralized by means of simple reduplication, while this pluralization strategy is not observed with lat-nouns. Instead, lat-nouns employ sideward reduplication, sideward reduplication with a simultaneous articulation of the second hand, and very seldomly also simultaneous articulation on its own. We propose that this unusual behavior is due to (i) a general markedness constraint which refers to the non-salience of one-handed lateral signs and (ii) the interpretation of the feature [lat] under reduplication.

With respect to (i), in OT accounts of spoken language reduplication, there is usually an interaction between BR-FAITH, IO-FAITH and more general markedness constraints. For instance, Alderete et al. (1999: 329) "assume that markedness constraints do not make morphological distinctions, so there is no such thing as a reduplicant-specific markedness constraint".[11] For NGT reduplication, too, it appears that a general markedness constraint comes into play. This constraint is grounded in perceptual salience. Indeed, perceptual salience has previously been taken into account in formalizations of spoken language reduplication. Wedel (1999) proposed constraints on emphatic reduplication in Turkish, where a CVC syllable is prefixed, of which the initial CV are identical to the initial CV of the stem, and the final C is taken from a restricted set of consonants. For the selection of the final C, he notes that high perceptual salience of the reduplicative morpheme is maintained: when bases that start with {b, m} undergo emphatic reduplication, "the otherwise primary affixal [p] may give way to the suppletive alternates {m, s} in order to maintain high perceptual salience of the reduplicative morpheme." This is captured in a markedness constraint that he names *SHAREDPLACE (Wedel 1999: 4). Similarly, in Amharic, reduplicative infixes that mark the plural on adjectives and the iterative on verbs target heavy syllables (Sande 2014). In this language, heavy syllables receive stress without exception; the reduplicative infixes thus target stressed positions, and if there is no heavy syllable in a word, i.e., when the infix may not be stressed, an alternative marking is used. As Sande (2014: 206) puts it: "It seems that in Amharic the pressure for an infix to be salient, in a prominent position, outweighs the pressure for that target landing site to be present in every word." This is captured in the constraint ALIGN-L(PLURAL, $\sigma_{\mu\mu}$), which requires the plural morpheme to align with the left edge of a heavy syllable (Sande 2014: 200).

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[11] We also see this in *the emergence of the unmarked* (TETU), where a markedness constraint that is normally outranked by an IO-FAITH constraint becomes important in the reduplicant, as it outranks BR-FAITH (McCarthy & Prince 1994).

While we obviously cannot postulate a constraint based on auditory salience, we will postulate one based on visual salience. During signed communication, addressees do not usually focus their eye gaze on the signer's hands, but rather on the face, where relevant grammatical information is encoded (Siple 1978; Neville & Lawson 1987). Indeed, while Neville & Lawson (1987) find that deaf participants show superior performance in processing peripheral visual stimuli as compared to hearing subjects, their results also indicate that deaf subjects were faster and more accurate in detecting direction of motion of central targets than for peripheral targets (Neville & Lawson 1987: 274). The observation that signers focus on each other's face during communication is also supported by historical tendencies in ASL. A diachronic study by Frishberg (1975: 703) shows that over time, the location of signs articulated below the neck (i) becomes more centralized, and (ii) moves up toward the hollow of the throat (for instance, ASL signs LIKE, FEEL, PLEASE, and LOVE moved from a location over the heart to the center of the chest). These diachronic tendencies suggest that signs articulated in the visual periphery are dispreferred, most likely because they are less visually salient to the observer. Signs articulated on the lateral side of the signing space in particular are in the periphery of the addressee's visual field. This observation and the fact that such signs are more salient if produced with both hands is captured in the markedness constraint in (7).[12]

(7) *[lat, 1H]: Assign a violation mark to any output realized with [lat] and [1H].

Although, according to a native signer, one-handed lat-nouns are less common than mid-nouns, they do exist in NGT. The constraint in (7) thus cannot be very high-ranked in this language, but it does seem to play a role in pluralization.

While this markedness constraint can account for the involvement of a second hand in the reduplication of lat-nouns, the observed sideward movement is still not accounted for. For this, we propose that the feature [lat] indicates a place of articulation that is relative: relative to the midsagittal plane in the default case, and relative to the base for a reduplicant. As a result, a reduplicant containing the feature [lat] automatically involves a further sideward movement with respect to the lateral base. For [lat] base nouns, a candidate with simple reduplication is thus automatically excluded by its inherent features, as copying the [lat] feature implies sideward movement. **Tableau 2** illustrates the choice of candidates for the lat-noun CHILD:

[12] Note that Pfau & Steinbach (2005b) also invoke the notion of salience in their account of the pluralization of lat-nouns in DGS. They argue, however, that it is the sideward movement of the reduplicants that enhances the salience of the sign. That is, for lat-nouns, sideward reduplication (which, according to them, is obligatory in DGS) should be more salient than simple reduplication.

	CHILD $\begin{bmatrix}1H\\lat\end{bmatrix}$	+ RED$_{PL}$	MAX-RED$_{PL}$	RED$_{PL}$ = σ	PLURAL-L	IDENT-BR-PLACE	IDENT-IO-[1H]	* [lat, 1H]
a)	$\begin{bmatrix}1H\\lat\end{bmatrix}$		*!					*
b)	$\begin{bmatrix}1H\\lat\end{bmatrix}$	$\begin{bmatrix}1H\\mid\end{bmatrix}$			*	*!		*
☞ c)	$\begin{bmatrix}1H\\lat\end{bmatrix}$	$\begin{bmatrix}1H\\lat\end{bmatrix}$			*			*
☞ d)	$\begin{bmatrix}2H\\lat\end{bmatrix}$	$\begin{bmatrix}2H\\lat\end{bmatrix}$			*		*	
e)	$\begin{bmatrix}2H\\lat\end{bmatrix}$			*!			*	

Tableau 2: Pluralization of the one-handed lat-noun CHILD.

Candidate a), without reduplication, violates MAX-RED$_{PL}$. Candidate b) is realized as a laterally articulated base with a reduplicant that is specified as [mid] instead of [lat]. This candidate therefore violates the constraint IDENT-BR-PLACE in (5) that we employed already in **Tableau 1**. Candidate c) has the feature [lat] in the reduplicant, which, as a consequence, is articulated lateral with respect to the base. All three candidates a)–c) violate the markedness constraint *[lat, 1H] because they have surface realizations with the non-salient feature combination [lat] and [1H]. Candidate d) avoids such a violation by employing a second hand (making the sign more salient through simultaneous articulation at both peripheral sides), which leads to a violation of IDENT-IO-[1H]. The last candidate, e), reduplicates via a simultaneous articulation, thereby violating IDENT-IO-[1H] and RED$_{PL}$ = σ. Winning candidates with the current ranking are c) and d), both having a separate syllable with the feature [lat] as reduplicant. We can see that in this case, it is the inherent place feature [lat] of the base and its faithful copy in the reduplicant leading to the sideward reduplicated allomorph of the plural (with or without simultaneous articulation) for lat-nouns.

That non-lateral noun types are not influenced in their choice of plural form by the newly introduced constraint *[lat, 1H] is obvious from its definition. **Tableau 3** shows this, and also illustrates that for two-handed nouns like the body-noun TROUSERS[13], there are no separate candidates for zero realization and simultaneous articulation. Both surface as candidate a)[14], which violates MAX-RED$_{PL}$ but not RED$_{PL}$ = σ, because a reduplicant is not discernible. A change in place feature for the reduplicant to [lat], as in candidate b), representing sideward reduplication, violates IDENT-BR-PLACE, leaving candidate c), with simple reduplication, as winner.

[13] Note that while the English gloss TROUSERS is inherently plural, this is not the case for the NGT sign.

[14] This only applies to symmetrical two-handed signs. For asymmetrical ones, the different handshapes or locations of the two hands would not allow for a simultaneous articulation. A more detailed OT-analysis would account for this with separate IDENT constraints for the features of the two hands.

	TROUSERS $\begin{bmatrix}\text{2H}\\\text{body}\end{bmatrix}$ + RED_{PL}		MAX-RED_{PL}	$\text{RED}_{\text{PL}} = \sigma$	PLURAL-L	IDENT-BR-PLACE	IDENT-IO-[1H]	* [lat, 1H]
a)	$\begin{bmatrix}\text{2H}\\\text{body}\end{bmatrix}$		*!					
b)	$\begin{bmatrix}\text{2H}\\\text{body}\end{bmatrix}$	$\begin{bmatrix}\text{2H}\\\text{lat}\end{bmatrix}$			*	*!		
☞ c)	$\begin{bmatrix}\text{2H}\\\text{body}\end{bmatrix}$	$\begin{bmatrix}\text{2H}\\\text{body}\end{bmatrix}$			*			

Tableau 3: Pluralization of the two-handed body-noun TROUSERS.

One-handed body-nouns were already dealt with in **Tableau 1**, and the addition of the low-ranked markedness constraint *[lat, 1H] does not change the winning candidate of simple reduplication.

For comp-nouns, we also observed only simple reduplication as realization of the plural reduplicant morpheme, and this is what the constraints introduced up to now and their ranking provide, see **Tableau 4** for the two-handed comp-noun TRAIN:

	TRAIN $\begin{bmatrix}\text{2H}\\\text{rep}\end{bmatrix}$ + RED_{PL}		MAX-RED_{PL}	$\text{RED}_{\text{PL}} = \sigma$	PLURAL-L	IDENT-BR-PLACE	IDENT-IO-[1H]	* [lat, 1H]
a)	$\begin{bmatrix}\text{2H}\\\text{rep}\end{bmatrix}$		*!					
b)	$\begin{bmatrix}\text{2H}\\\text{rep}\end{bmatrix}$	$\begin{bmatrix}\text{2H}\\\text{lat}\end{bmatrix}$			*	*!		
☞ c)	$\begin{bmatrix}\text{2H}\\\text{rep}\end{bmatrix}$	$\begin{bmatrix}\text{2H}\\\text{rep}\end{bmatrix}$			*			

Tableau 4: Pluralization of the two-handed comp-noun TRAIN.

Candidate b) violates IDENT-BR-PLACE as the reduplicant has the place feature [lat], while the base does not.

One-handed comp-nouns in NGT (e.g., SIREN) are predicted to behave the same with respect to pluralization, based on these constraints and their ranking, though we cannot confirm this as we did not include such signs in our data collection (and no such signs were extracted from the corpus).

For mid-nouns, the present analysis would also predict simple reduplication as winning candidate. However, our data showed that mid-nouns sometimes exhibited additional sideward reduplication, which would incur a violation of IDENT-BR-PLACE, similar to the one by the sideward reduplicant candidate b) in **Tableau 4**. We can also see from **Tableau 4** that candidate b) with sideward reduplication is harmonically bounded by candidate c) with simple reduplication, i.e., that, independent of the ranking, candidate c) would always win with the current constraints. For mid-nouns, we thus need to introduce an additional constraint that disfavors simple reduplication, and instead prefers non-identity in the location features of base and reduplicant.

For spoken languages, it has been observed that non-identity between base and reduplicant may be preferred. For instance, Yip (1995: 241) discusses "identity avoidance in morphology", which she divides into four categories, one of which is "the output of reduplication cannot be total identity". An example is "echo-words", for instance, English *table-schmable*. Yip (1995) proposes that this results from a tension between a constraint that requires repetition (REPEAT), and one that prevents repetition, i.e., that avoids identity (*REPEAT). If the latter outranks the first, we get an output such as *table-schmable*, that is, reduplication without complete identity.[15] Similarly, see also Kentner (2017) for constraints preferring non-identity in German reduplication.

A markedness constraint against BR-FAITH for reduplicated mid-nouns is provided in (8), though we have to admit that, at least for now, we cannot offer a perceptual or physiological motivation for this constraint, except for a general tendency to avoid identity in morphology (Yip 1995). It is not clear why this tendency would specifically apply to NGT mid-nouns, however, and therefore the constraint is of an ad-hoc nature.

(8) *BASE [mid] – RED [mid]: Assign a violation mark to any output of base and reduplicant both being realized as [mid].

Tableau 5 illustrates the workings of this constraint with the example of the two-handed mid-noun BOOK. Recall from footnote 4 that in NGT, one-handed mid-nouns are all body-anchored (such as, e.g., APPLE), and therefore fall into the body-noun category in our categorization.

BOOK + RED_{PL} $\begin{bmatrix}\text{2H}\\\text{mid}\end{bmatrix}$	**MAX-RED_{PL}**	**$\text{RED}_{\text{PL}} = \sigma$**	**PLURAL-L**	**IDENT-BR-PLACE**	***BASE [mid] RED [mid]**	**IDENT-IO-[1H]**	***[lat, 1H]**
a) $\begin{bmatrix}\text{2H}\\\text{mid}\end{bmatrix}$	*!						
☞ b) $\begin{bmatrix}\text{2H}\\\text{mid}\end{bmatrix}$ $\begin{bmatrix}\text{2H}\\\text{lat}\end{bmatrix}$			*	*			
☞ c) $\begin{bmatrix}\text{2H}\\\text{mid}\end{bmatrix}$ $\begin{bmatrix}\text{2H}\\\text{mid}\end{bmatrix}$			*		*		

Tableau 5: Pluralization of the two-handed mid-noun BOOK.

[15] In fact, REPEAT has the same effect as McCarthy & Prince's (1993b et seq.) IDENT-BR and MAX-BR, as Yip (1995) points out. Yip (1995) makes clear that the REPEAT constraint forces reduplication by itself, and does not presuppose RED in the input. We do postulate RED in our input, and thus we do not assume (*)REPEAT constraints.

The newly introduced constraint (8) and its ranking at the same height as IDENT-BR-PLACE ensures the observed two reduplication forms for mid-nouns and does not change the outcome of any of the earlier tableaux, as none of them had a mid-noun as base.

3.3 Ranking values to replicate the variation in output forms

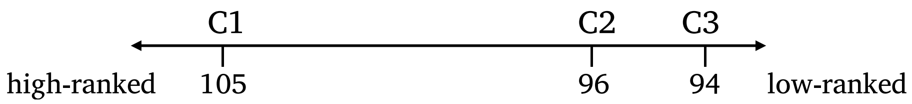
Up to now, we have introduced the relevant constraints and demonstrated how they are violated by the different noun types, assuming a preliminary ranking that could account for some variation in **Tableaux 2** and **5** by predicting two winners, both occurring 50% of the time. This preliminary ranking, however, did not allow for zero-marking to win. We now turn to the question whether the constraints can be ranked in such a way that they replicate all the variation in output forms that we observed in our data, including zero marking, and a distribution of winners that is more in line with the actually occurring distribution.

The availability of different reduplication types for one and the same noun, as observed in NGT, is also attested in some spoken languages. Hayes & Abad (1989) report that in Ilokano (Austronesian), reduplication can take different forms when the stem starts with a consonant plus glide cluster. For instance, three options are available for plural reduplication of [rwáŋan] 'door', as illustrated in (9) (for more details, see Hayes & Abad 1989).

(9) rwá.ŋan ruː.rwá.ŋan ~ rur̥.wá.ŋan ~ rwaŋ.rwá.ŋan
'door' 'doors' [*Ilokano*; Hayes & Abad 1989: 365]

In order to account for such variation in forms, Boersma (1997) and Boersma & Hayes (2001) developed stochastic OT. In this framework, constraints do not show categorical ranking, but are ranked along a continuous ranking scale with arbitrary units, as exemplified with three constraints and their ranking values in (10) (based on Boersma & Hayes 2001: 47).

(10)



In (10), the distance between constraints C1 and C2 is larger than that between C2 and C3, indicating that the relative ranking between C1 and C2 is more fixed than that between C2 and C3. At every instance when a winner of an OT tableau has to be determined, that is, at evaluation time, some small noise is added to the ranking value of each constraint, resulting in a so-called selection point for each constraint. The constraints are then ordered according to their selection points, and the winning candidate is determined. The value of the noise added to the ranking value at evaluation time is drawn from a Gaussian distribution of values that is based on previously determined evaluation noise: a small value on the ranking scale, which is the same for all constraints. For instance, if we assume an evaluation noise of 3, the selection points for C1 in

(10) would lie between 105 ± 3, i.e., 102–108, with values towards the edges of this range much less likely than values close to its center. Two constraints like C2 and C3 that are fairly closely ranked with respect to each other on the ranking scale can have a reverse ranking C3 ≫ C2 at a specific evaluation time, e.g., if C2 has added noise of –1.6 and a resulting selection point of 94.4, and C3 has added noise of 0.7 and a resulting selection point of 94.7. Over many evaluations, such cases result in multiple outputs for a single underlying form. In this way, stochastic OT allows for the inclusion of variation, and more specifically, it enables us to determine the exact occurrence frequency of specific output forms.

With the Gradual Learning Algorithm (Boersma & Hayes 2001), the ranking values of involved constraints can be acquired on the basis of the distributions of observed output forms. This acquisition process can be simulated: for this purpose, we used OTMulti grammar in Praat (Boersma & Weenink 2020).

We defined all constraints, the output candidates for the noun-types, and their constraint violations, as given in Sections 4.1 and 4.2, in an OTMulti grammar, which is provided in Appendix C1. The initial grammar had the ranking values of all constraints set at 100 (no inherent ranking yet). This grammar then learned the ranking values of its constraints, that is, changed these values on the basis of the data it was given. This data consisted of input-output pairs, where the input was one of the four NGT noun types, and the output one of the occurring plural realizations for the given input. These pairs were drawn from a distribution we defined on the basis of our observed forms (**Table 1**), repeated here (without overall amounts and shading) in **Table 2**.

Type	Zero marking	Simple reduplication	Sideward reduplication	Simultaneous articulation	Sideward and Simultaneous reduplication
body	40.2%	55.7%	3.2%	1.1%	0%
comp	57.5%	37.5%	5%	0%	0%
lat	15.6%	1.8%	67.9%	1.8%	12.9%
mid	43.2%	29.7%	21.6%	0%	0%

Table 2: Pluralization strategies and their occurrence frequencies as defined in the input of our simulation.

We also included all cases that occurred less than 5% of the time in our real data, meaning that in **Table 2**, we do not make a distinction anymore between white and shaded cells as we did in **Table 1**. For the input body-noun, for instance, the output we provided to our grammar was thus 40.2% zero marking, 55.7% simple reduplication, 1.1% simultaneous articulation, and 3.2% sideward reduplication. The full input-output pair distributions are provided in Appendix C2.

From these pair distributions, one input-output pair was drawn at a time and fed to the grammar. For each pair, the grammar produced an output on the basis of its current constraint ranking, and compared the produced output to the expected output that was provided as part of the input-output pair. If the two were identical, then the constraint ranking stayed the same. If there was a discrepancy between actually produced input and expected output (as provided in the input-output pair), then the constraint ranking was adjusted. This adjustment is illustrated in **Tableau 6** below with an intermediate learning stage for an input comp-noun. All constraints that were violated by the candidate that did win in the actual production (indicated by ☞) were promoted (indicated by the left arrow), and all constraints that were violated by the candidate that should have won according to the input-output pair (indicated by ✓) were demoted (indicated by the right arrow). Promotion and demotion on the ranking scale was performed by a previously defined learning step.

	100.76	**100.61**	**100.56**	**99.53**	**99.18**	**98.77**	**97.73**
$\begin{bmatrix}\text{2H}\\ \text{rep}\end{bmatrix}$ + RED$_{\text{PL}}$	**PLURAL-L**	**RED$_{\text{PL}}$ = σ**	**IDENT-BR-PLACE**	**MAX-RED$_{\text{PL}}$**	***BASE [mid] RED [mid]**	**IDENT-IO-[1H]**	***[lat, 1H]**
☞ a) $\begin{bmatrix}\text{2H}\\ \text{rep}\end{bmatrix}$				← *			
b) $\begin{bmatrix}\text{2H}\\ \text{rep}\end{bmatrix}$ $\begin{bmatrix}\text{2H}\\ \text{lat}\end{bmatrix}$	*!		*				
✓ c) $\begin{bmatrix}\text{2H}\\ \text{rep}\end{bmatrix}$ $\begin{bmatrix}\text{2H}\\ \text{rep}\end{bmatrix}$	*! →						

Tableau 6: Learning tableau for a comp-noun with ranking values plus small evaluation noise at evaluation time given on top of each constraint. ☞ indicates the candidate that did win according to the current constraint ranking, and ✓ the candidate that should have won according to the provided input-output pair. The left arrow next to the violation mark indicates that this constraint will be promoted, the right arrow that the constraints will be demoted.

This stepwise promotion and demotion of constraints is the basic characteristic of the Gradual Learning Algorithm (GLA; Boersma & Hayes 2001), which differs, e.g., from Error-Driven Constraint Demotion (EDCD), an algorithm for OT learning proposed by Tesar & Smolensky (1996). The latter only allows the demotion of constraints and is not gradual, which means that each data point results in a change in the absolute ranking of the constraints. In contrast to EDCD, the GLA enables the learner to acquire a grammar that can account for variation, as illustrated by Boersma & Hayes (2001).

In total, 100,000 tokens of input-output pairs were fed to our grammar, and the grammar stepwise acquired a constraint ranking that attempts to replicate the given input distribution (with all specifications set to the standards in Praat). The newly learned grammar was then evaluated by feeding it 100,000 times input candidates, i.e., one of the four noun types at a time, all four equally often. We repeated this learning procedure 100 times (100 different learners). The ranking of the constraints and their mean ranking values is given in **Table 3**, and the mean output frequencies for all four possible input forms are summarized in **Table 4**.

RED$_{PL}$ = σ	MAX-RED$_{PL}$	PLURAL-L	IDENT-IO-[1H]	* [lat, 1H]	IDENT-BR-PLACE	*BASE [mid] RED [mid]
102.0	98.2	98.0	78.2	76.1	–336.8	–336.8

Table 3: Ranking of the constraints in the 100 grammars, with their mean ranking values in the second row.

Type	Zero marking		Simple reduplication		Sideward reduplication		Simultaneous articulation		Sideward and Simultaneous reduplication	
body	40.2%	39.7%	55.7%	59.1%	3.2%	0%	1.1%	1.9%	0%	0%
comp	57.5%	40.3%	37.5%	59.7%	5%	0%	0%	0%	0%	0%
lat	15.6%	39.4%	1.8%	0%	67.9%	45.6%	1.8%	1.9%	12.9%	13.0%
mid	43.2%	40.3%	29.7%	29.9%	21.6%	29.8%	0%	0%	0%	0%

Table 4: Pluralization strategies per noun type. Left columns: observed frequency (cf. Table 2), right columns: mean occurrence frequencies in the output of our simulations. Color indicates how far these frequencies depart from the observed frequencies: white = ±5%, light grey ±10%, dark grey >10%.

A comparison of the output frequencies produced by our grammar (right columns for each strategy) and the observed frequencies in the data (left columns) shows that the overall variation in forms is represented correctly via the learned constraint ranking: the noun-types exhibit the plural markings that we observed in the data.

For body- and mid-nouns, the results of the simulation are in line with the observed distribution of the strategies, while for lat- and comp-nouns this is not the case. For comp-nouns, the discrepancy between observed distribution and the distribution predicted by our formalization might be caused by the fact that the real data is skewed: comp- and mid-nouns, with 40 and 37 tokens, respectively, are underrepresented in our data compared to body-nouns with 185 and lat-nouns with 224 tokens. A larger database with a more balanced distribution of types, i.e., more comp-nouns, might provide frequencies that are more in line with the distributions predicted for this noun type. For lat-nouns, this explanation does not apply, and we cannot currently account for the discrepancy in occurrences apart from pointing out that with the constraint set that we employ (especially the general constraints RED$_{PL}$ = σ, PLURAL-L and MAX-RED$_{PL}$ that do not distinguish between the noun types), we predict a similar occurrence of zero marking for all four noun types.

It is important to note that when accounting for the variation in our data by one grammar, we assume that the signers all show the same variation and that their behavior can indeed be captured by a single grammar. However, we did not only observe intra-signer variation in the data, but also different patterns across signers (as mentioned in Section 2). These patterns across signers could in principle be so radically different that they are better described by two (or more) different grammars. As an example, one group of signers could use sideward reduplication of lat-nouns very frequently while another group could not use it at all, requiring two grammars with fundamentally different rankings of the respective constraints. Future work should investigate such intra-signer variation and possible user types, in order to determine how such variation can be captured with different grammars (for an example from L2 acquisition, see Hamann 2009).

4 Discussion

4.1 The modality-(in)dependence of OT-constraints

With the constraints that we introduced in Section 3, we successfully captured the patterns of pluralization in NGT as observed by van Boven (2021), and by using stochastic OT, we could, to a large degree, also account for the variation found in the use of plural allomorphs. In our formal analysis, we motivated the choice of constraints that have previously been used in formalizations of spoken language, that is, constraints that are maximally modality-independent. Indeed, on the one hand, it is clear that OT and the constraint types proposed for spoken language reduplication work for sign language data as well. We employed IO-FAITH, BR-FAITH, ALIGNMENT constraints, and a constraint on the form of the reduplicant, together with phonologically- and phonetically-motivated co-occurrence restrictions, all of which are commonly used in formal accounts of reduplication in spoken languages and are shown to work equally well for NGT. The constraints MAX-RED, ALIGN and $\text{RED}_{\text{PL}} = \sigma$ involve completely modality-independent notions, such as the reduplicant plural morpheme and the syllable.

Yet, on the other hand, the fact that we formalize *sign language* data has the unavoidable consequence that some of the constraints involve modality-specific features, in other words, the featural implementation is modality-specific (see Section 2.3). While our IO- and BR-FAITH constraints are of the same *type* as those proposed for spoken languages, they involve, for example, the features [mid] and [1H], both of which are clearly modality-specific. The same applies to *[lat, 1H]: while some spoken language accounts also involve constraints motivated by perceptual salience, our constraint is necessarily motivated by *visual* rather than auditory salience, employing features that simply cannot exist in the spoken language modality. Even a general ALIGNMENT constraint comes with a modality-specific flavor: simultaneous alignment in a sign language is, of course, modality-specific and not the same as spoken language phenomena formalized by ALIGNMENT, such as infixation of the reduplicant (recall Riggle 2006). We thus used modality-independent constraint types (that are properties of the OT framework) and stochastic OT to handle modality-specific features.

Taking a more general perspective on the subject matter, Chomsky (2007: 22) claims that sign language research actually provides us with evidence "that externalization appears to be independent of sensory modality" (cf. also Chomsky 1965; 2000). Sandler (2017), however, does not fully agree with this generalization, as this would imply that phonology is essentially the same in both modalities. While she agrees that both modalities have a phonological level, suggesting in some sense a shared cognitive system, she emphasizes that "ubiquity can be deceptive if it prevents us from looking further to understand the nature of this commonality, as well as the nature of the differences" (Sandler 2017: 58). Indeed, phonological features, being tied to articulatory systems, are clearly not universal (Sandler 2017), and previous studies have repeatedly shown that the modality of signal transmission shapes language (e.g., MacNeilage 2008; Sandler 2013; 2017, among others). Our study adds to this, as we show that the specific motor system a language relies on has consequences for analyses within the OT framework, too – not necessarily on the general level of constraint types, but rather for the featural implementation.

We are not the first to formalize sign language plural reduplication in OT – Pfau & Steinbach (2005b) present an OT-analysis of pluralization in DGS, a language which also employs simple and sideward reduplication in pluralization. They introduce six constraints, the ranking of which successfully derives the patterns observed for DGS. Still, when comparing our formal account to that of Pfau & Steinbach, it is clear that they employ more modality-specific notions in their constraints. For instance, our ALIGNMENT constraint does away with their modality-specific constraint *MOVE that blocks the addition of a sequential movement to the input. Moreover, Pfau & Steinbach formulate several faithfulness constraints, but they only take into account IO-FAITH; notably, the potential role of BR-FAITH is ignored. A further difference to the analysis by Pfau & Steinbach is that while they assumed sideward reduplication as default realization of the plural, our analysis with the high-ranked constraint MAX-RED$_{PL}$ only requires some kind of reduplication, and high-ranked RED$_{PL}$ = σ demands that the reduplicant is a syllable on its own. The ranking of these two together with BR-FAITH and IO-FAITH and two noun-type specific markedness constraints determines the optimal reduplication strategy for each noun type. Our formalization is thus innovative in that it shows that notions from formalizations of spoken language reduplication can be integrated in a formal account of sign language data.

While the analysis by Pfau & Steinbach only accounts for obligatory, categorical patterns, we also account for the variation in our data. We are convinced that the categorical nature of Pfau & Steinbach's data can be explained by different methodologies. Pfau & Steinbach based their analysis only on elicited plural forms from DGS signers. In contrast, our point of departure were naturalistic corpus data, and it is a well-known fact that corpus data commonly present us with more variation than one might expect – as Johnston et al. (2007) aptly put it in their title: "real data are messy". In fact, such, often unexpected, variation has been documented for NGT, based on data extracted from the Corpus NGT, for various grammatical domains (e.g., Bank 2014; Legeland 2016; Oomen & Pfau 2017; Klomp 2019). We are the first to analyze sign language variation using stochastic OT, and we did this in the same way as Boersma & Hayes (2001), who formalize free variation in Illokano (see Section 3.3). Indeed, as they point out referring to Labov (1974; 1994), the field of sociolinguistics has often shown that free variation is ubiquitous in natural language use. Boersma & Hayes show that the Gradual Learning Algorithm is capable of simulating such variation in a spoken language, and our study shows that exactly the same is true for sign language data.

4.2 Reflections on the formalization in light of typological variation

The present analysis shows that constraint types introduced to formalize spoken language reduplication can be used to formalize data from NGT. However, to gain stronger evidence for the modality-independence of constraint types, formalizations of reduplication in other sign languages are necessary. We will not offer such evidence here, but our formalization does make certain predictions with respect to (sign) language typology – after all, one of the hallmarks of OT is that the theory strives to account for cross-linguistic variation by means of language-specific constraint rankings. It is therefore worthwhile to briefly consider how our account fares when it comes to intra-modal variation. It is well-known that sign languages display striking similarities in the realm of morphology (Aronoff et al. 2005b; Meir 2012). Still, even when it comes to simultaneous morphological processes, we do find some variation: a certain morphological process may simply not be attested in a given sign language or be very infrequent, or it is attested but applies in a different way or to a different class of signs; see, for instance, Zeshan (2003) and Nyst (2007) for classifiers in Indopakistani Sign Language and Adamorobe Sign Language (Ghana), and Padden et al. (2010) and Bauer (2014) for spatial agreement in Al-Sayyid Bedouin Sign Language (Israel) and Yolngu Sign Language (Australia). As already briefly alluded to in Section 2.2, such cross-linguistic variation is also attested in the domain of pluralization (see also Pfau & Steinbach 2006).

Let us consider DGS again, and let us assume that the DGS patterns are in fact as categorical as Pfau & Steinbach (2005b) report. Ranking the constraints that we introduced differently could derive most of these patterns in a straightforward way. First, DGS lat- and mid-nouns are always overtly marked for plurality, suggesting that MAX-RED$_{PL}$ is high-ranked in this language. As DGS mid-nouns undergo simple but not sideward reduplication, the constraint *BASE[mid]-RED[mid] would be very low ranked. Recall also that in DGS, body- and comp-nouns are always zero-marked.

This suggests that our analysis would need to be supplemented by a further constraint banning any kind of reduplication for body- and comp-nouns. In fact, body- and comp-nouns have also been found to undergo zero marking in other sign languages (e.g., Pizzuto & Corazza 1996 for Italian Sign Language; Sutton-Spence & Woll 1999 for British Sign Language), supporting this assumption.

Furthermore, the constraint MAX-RED$_{PL}$ and the ALIGNMENT constraint PLURAL-L are closely-ranked in our account, allowing for alternation between zero-marking and plural marking via reduplication. A higher ranking of MAX-RED$_{PL}$ would predict languages without zero marking, and a lower ranked MAX-RED$_{PL}$ would yield languages in which the plural does not have to be marked at all. While we are not aware of a sign language of the former type, the latter pattern has been described for Indopakistani Sign Language, where Zeshan (2000) observes that no distinction is made between the singular and plural of nouns, that is, only the zero-marking strategy is applied, independent of noun type.[16]

Finally, IO-FAITH constraints for other features than handedness were not included in our analysis but assumed to be ranked very high, predicting languages where IO-FAITH is lower ranked, particularly below ALIGNMENT constraints like PLURAL-L, which would allow changes in the stem features of the noun.[17] This is in fact found in certain spoken languages, for instance, languages that allow for morphological tones or vowel fronting (umlaut) to mark the plural.

4.3 Topics for future research

While Section 3 makes clear that our data – including the variation we find – can successfully be formalized in OT, some observations were not accounted for. These data points merit some discussion.

Our analysis focuses on the main pluralization strategies in NGT, that is, the strategies described in Section 2.2 that occur most regularly. Still, two nouns – lat-noun PERSON and body-noun HUMAN – show alternative pluralization strategies that were not taken into account in our formalization. PERSON (**Figure 4b** in Section 2.2, but also shown here with a still from the Corpus NGT in **Figure 14a**) is a one-handed noun and commonly undergoes (simultaneous) sideward reduplication, like other lat-nouns. However, recall from footnote 3 that under simultaneous sideward reduplication of this specific noun, the hands move alternately rather than in parallel (N = 3, by three different signers in the corpus data), illustrated already in **Figure 9c**, but also

[16] Zeshan further notes that the only noun that undergoes morphological plural marking with some frequency is CHILD. This sign is identical to the NGT sign (see Figure 4a), and just as in NGT, it is pluralized by means of sideward reduplication. Still, for IPSL, we have to assume that this a lexicalized, i.e., idiosyncratic, plural form (comparable, for instance, to English *mouse* – *mice*).

[17] Such changes in the features of the stem do occur for verbs under iterative aspect marking in NGT (van Boven Under review).

shown here with stills from the Corpus NGT in **Figure 14b**. In our analysis above, we did not differentiate the alternating movement, and we consider this an avenue for future research, as it is still unclear whether this strategy can also apply to other (lat-)nouns in NGT. Recall from Section 2.2 that simultaneous reduplication may also involve alternating movement in ASL (Wilbur 1987) and Austrian Sign Language (Skant et al. 2002).

Figure 14: Lat-noun PERSON (a) [CNGT0833; s035; 03:04.64] undergoing simultaneous sideward reduplication with alternating movement (b) [CNGT0862; s040; 03:57.36].

The second noun, the one-handed noun HUMAN (already illustrated in **Figure 2b**, and here also with a still from the Corpus NGT in **Figure 15a**), is articulated on the lateral side of the chest; the hand moves downward while maintaining contact with the chest. While this noun – like the other body-nouns in our study – can undergo simple reduplication and zero marking, it also shows an additional strategy: simultaneous reduplication, i.e., there is not only simultaneous articulation, but both the dominant and the non-dominant hand simultaneously and repeatedly perform the downward movement as in **Figure 15b** (N = 24).

Simultaneous reduplication was not attested for any of the other nouns. Two potential explanations can be offered: (i) for some signers, the base-form of HUMAN is not one-handed (as in **Figures 2b** and **15a**) but two-handed or has a two-handed variant, or (ii) simultaneous reduplication is an additional strategy. In our analysis we assumed explanation (i) and included this strategy under ‘simple reduplication’. Yet, since we could not check the base-form of HUMAN for each signer – it was not a target noun in the elicitation – we should not completely rule out the second explanation that HUMAN can undergo simultaneous reduplication. HUMAN may be a lexical exception and thus the only noun (or one of few nouns) in NGT of which the plural is marked in this way. Such exceptions also occur in spoken languages, for instance in English: although the language has phonologically triggered allomorphy in pluralization, the plural of specific nouns is lexically determined, i.e., idiosyncratic (for instance, zero marking for *sheep* and the vowel alternation for *mouse* – *mice*). Still, for NGT, we cannot exclude the possibility that simultaneous reduplication applies to more nouns since not all nouns were included in our data set.

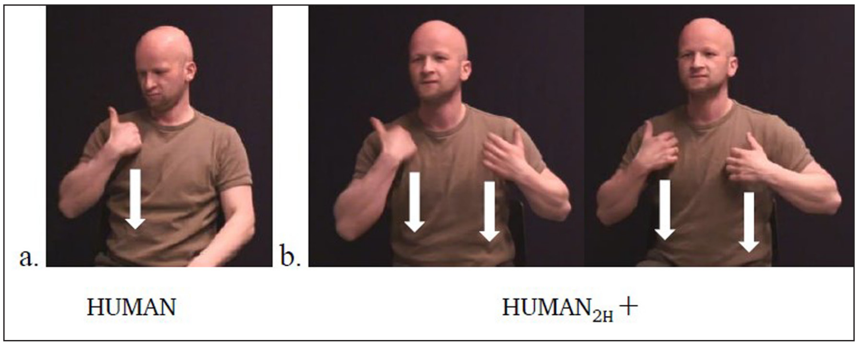


Figure 15: Body-noun HUMAN (a) [CNGT0208; S012; 05:47.88] undergoing simultaneous reduplication (b) [CNGT0208; S012; 05:42.96].

If simultaneous reduplication is indeed an additional strategy, we can hypothesize which phonological features trigger it. Recall that we follow Pfau & Steinbach (2005b) in assuming the hierarchical feature classification in **Figure 1** (Section 2.1). Following this hierarchy, body-noun HUMAN is only specified for [body] and [contact]. Yet, if we forget about the hierarchy for a moment and further look at the features of this noun, we note that it is articulated at the lateral side of the chest. The two-handed realization is then not surprising, since pluralized lateral nouns prefer a simultaneous articulation by the second hand, as we implemented with the markedness constraint *[lat, 1H]. This shows that by assuming the feature classification in **Figure 1**, some more specific feature specifications are lost. This clearly applies to comp-nouns as well, where we assume no place features altogether.

This latter point made us wonder whether we should let go of the hierarchical structure of features, and instead evaluate all possible place and movement features for each noun. Yet, looking at the data more closely suggests that this may not be necessary. First, unlike lat-nouns, simultaneous reduplication of HUMAN did not involve sideward movement. Apparently, the noun adheres to our constraint IDENT-BR-PLACE in such a way that the (main) place of articulation in the reduplicant is [body] and not [lat], suggesting that the first is indeed the more prominent feature. As for comp-nouns, our current OT formalization predicts that sideward reduplication is never preferred when the noun has inherent repetition, regardless of its exact place of articulation. Indeed, we asked a native signer if sideward reduplication of the one-handed noun AGE – which has a repeated movement and is articulated laterally – would be possible, but she indicated that this is definitely not the case. This suggests that the underlying place of articulation feature is irrelevant in pluralization of comp-nouns, and therefore – as a result of our IDENT-BR-PLACE constraint – that the reduplicant can never have a feature [lat]. In other words: if comp- and body-noun types were specified for [lat], we would expect a copy of that feature in the reduplicant, resulting in sideward reduplication – this does not happen, however. Finally, when trying out this alternative classification, the four noun types identified in the hierarchical structure (Pfau & Steinbach 2005b) still grouped together with respect to the pluralization strategies they undergo. For these reasons, we decided to maintain the original classification.

5 Conclusion

OT-formalizations have been fruitfully applied to a wide range of reduplication patterns in typologically diverse spoken languages, taking into account the amount of material that is copied in the process, the degree to which this material is identical to or different from the base, and the exact position of the reduplicated material. Moreover, two previous studies have attempted to capture reduplication phenomena in a sign language, viz. DGS (Pfau & Steinbach 2003; 2005b). In the present study, we offered a detailed investigation of plural reduplication in NGT, aiming to include modality-independent notions in our formalization.

Our data show that pluralization in NGT involves phonologically triggered allomorphy. However, there is no one-to-one relation between a specific noun type and the allomorph it selects. Rather, each noun type may combine with two to three different allomorphs, and for all noun types, one of these allomorphs is zero marking. By means of several constraints and a formulation and simulation within stochastic OT, we can account for the attested patterns as well as most of the variation. Importantly, the constraint types we employ in our formalization are modality-independent, as they concern input-output and base-reduplicant faithfulness, marked feature combinations, and alignment. What is, of course, specific to the visual-spatial modality of sign languages are the phonological features that the constraints refer to (e.g., [lat], [mid], [1H]).

Future studies on NGT should address the gaps in our data set that we acknowledged, as well as the few exceptions that we reported. Also, it is hoped that a similar approach will be applied to other sign languages, in order to broaden our understanding of intra-modal typological variation and, subsequently, to test in how far modality-independent constraint types and their (re) ranking are able to capture this variation. For the case of mid-nouns and the ad-hoc constraint BASE[mid]-RED[mid], we hope that future studies on NGT, as well as other sign languages, will provide motivations for this constraint, thereby contributing to the still rather small but growing number of OT-accounts of sign languages.

Abbreviations/glossing conventions

SIGN	The gloss of one single sign.
SIGN.SIGN	Multiple words form the gloss of one single sign.
$\text{INDEX}_{1,\ 3A}$	Pointing sign with a linguistic function (pronoun); subscript number refers to locations in the signing space: 1 = the chest of the signer, 3a/3b = right or left in the signing space.
INDEX_{ARC}	Pointing sign with a linguistic function (pronoun); subscript refers to the arc shape of the movement, which indicates that the pronouns refers to multiple referents.
SIGN+++	Reduplication of a sign; number of pluses indicates number of repetitions.
SIGN>+>+	Sideward reduplication of a sign; number of pluses indicates number of repetitions.
SIGN_{2H}	One-handed base sign articulated by two hands.
$\text{SIGN}_{2H.ALT}$	One-handed base sign articulated by two hands moving alternately.
[CNGTx; Sx; x:x]	Corpus NGT file number; signer number; begin time (m:s.ms).
[p0x]	Participant number in elicited data.

Data availability

The Corpus NGT is openly available at www.corpusngt.nl and https://archive.mpi.nl/tla/islandora/object/tla:1839_00_0000_0000_0004_DF8E_6?asOfDateTime=2018-03-02T11:00:00.000Z. The elicited video data cannot be publicly shared to protect the privacy of the participants. The data are reported in more detail in van Boven (2021), and the elicitation method is reported in more detail in van Boven (2020). An English translation of the complete elicitation task, including the instructions, and all data annotations of both the corpus data and elicited data are openly available:

van Boven, Cindy. 2023. Annotations of plural reduplication in NGT (corpus & elicited data). University of Amsterdam / Amsterdam University of Applied Sciences. DOI: 10.21942/uva.23260814

Additional files

The additional files for this article can be found at this link: https://doi.org/10.16995/glossa.9686.s1

They include the following materials:

- **Appendix A.** Nouns across noun types in the corpus and elicited data (adapted from van Boven 2021: 355).

- **Appendix B.** Detailed overview of pluralization strategies for different sub-types of body- and comp-nouns.
- **Appendix C1.** OTMulti grammar.
- **Appendix C2.** Input-output distribution.

Ethics and consent

Work with human subjects, as reported in this study, has been approved by the Ethics Committee of the Faculty of Humanities of the University of Amsterdam, dossier number 2019-FGW_SIGN-11354.

All participants signed an informed-consent form. By signing this form, they agreed (i) to participate in the research, and (ii) that results are reported anonymously in academic publications. Additionally, participants signed a separate form in which they indicated whether they also permit the publication of (stills from) video's in publications. This was part of ethics approval.

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Competing interests

The authors have no competing interests to declare.

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