This-one-great-study or *Study-great-one-this*?
On the modality-specificity of a cognitive preference for the N-A-Num-Dem order

Sigrid Bruinsma (14639254)

Cognition, Language and Communication, Universiteit van Amsterdam

Bacheloronderzoek Cognition, Language and Communication

Onder begeleiding van dr. Roland Pfau

24-06-2025

9918 words

Abstract

Spoken languages tend to order elements of a noun phrase according to three cognitive preferences, namely 1) to order the adjective closest and demonstrative farthest from the noun (homomorphism), 2) to place the noun at one of the phrase boundaries (harmony), and 3) to position modifiers postnominally. Together, these preferences result in the cognitively and typologically preferred order N(oun)-A(djective)-Num(eral)-Dem(onstrative). The aim of this study was to assess whether this cognitive preference holds in the visual modality when a linguistic system is present. To this end, an artificial language learning experiment was set up with a between-subjects design (n=46). Participants were divided into two groups that both learned a sign system. The systems differed in sign order, either N-A-Num-Dem or Dem-Num-A-N, hereby targeting the postnominal modifier preference. After a learning phase, participants performed a noun phrase-picture matching task which measured reaction time as a function of cognitive processing load. The results showed no significant difference in reaction time between groups (p = 0.46), thus failing to establish a cognitive preference.

Table of contents

1 Introduction

While the question whether language shapes cognition is controversial, the idea that cognition shapes language is intuitively more compelling, as language is a product of human cognition. If cognitive biases influence language, these biases should be expressed cross-linguistically in dominant linguistic patterns. These patterns do occur, and some of them are captured by Greenberg's (1963) set of so-called Universals. However, linguistic patterns need not be universal, as a cognitive bias is merely a preference that can be violated. The most widely known example is the cross-linguistic tendency to encode the agent before the patient, which is thought to result from a cognitive agent bias (Dryer, 2013d; Greenberg, 1963; Wilson et al., 2022). This agent bias seems to be amodal (non-modality-specific) as it also shapes constituent order in sign languages (Napoli & Sutton-Spence, 2014), but a cognitive bias could be modality-specific (Perniss et al., 2007; Zeshan & Palfreyman, 2020). Examples like these show the significance of sign languages to linguistic typology and also cognitive linguistics, because cross-modal linguistic patterns give insight into the cognitive affordances of language. Consequently, they inform theories on the origin and evolution of language (Sandler, 2013).

Knowing if and how a linguistic pattern holds cross-modally also helps to inform about the nature of the presumed underlying cognitive bias. For instance, non-decimal numeral systems are rare in spoken languages, but their occurrence is even rarer in sign languages, because counting with the hands affords a natural five-base or ten-base system (Zeshan & Palfreyman, 2020). As spoken languages can also associate a numeral system with the hands, it seems that counting with the hands underlies the rare occurrence of non-decimal numeral systems across languages and modalities (Zeshan & Palfreyman, 2020). In this way, cross-modal typology can help to pinpoint the cognitive source of a linguistic pattern. The current study utilises this reasoning to further elucidate the nature of a cognitive preference underlying dominant word order in a complex noun phrase (NP) containing a noun (N), adjective (A), cardinal numeral (Num) and demonstrative (Dem)[1].

Within a complex noun phrase, the most frequent word order cross-linguistically is N-A-Num-Dem, followed by Dem-Num-A-N (Dryer, 2018). Together, these orders are referred to as isomorphic and they form a subset of eight orders that are called homomorphic (for definitions of these terms, see Section 2) (Culbertson et al., 2020b). The dominance of the head-initial (N-A-Num-Dem) over the head-final (Dem-Num-A-N) isomorphic complex noun phrase is seen as the result of a cognitive preference for postnominal modifiers, but its nature, when and why postnominal modifiers are preferred, is uncertain. It is as of yet unknown whether the bias is modality-specific and only manifests in spoken languages, or whether it is amodal and also shapes noun phrase sign order across sign languages.

Previous typological research on NP sign order is limited to individual sign languages (Brunelli, 2011; Mantovan & Geraci, 2017; Rutkowski et al., 2015; Zhang, 2007), or only a few NP-internal elements, such as the head and one modifier (Coons, 2022). As for gesture experiments, previous research has investigated a homomorphism bias (Culbertson et al.,

---

[1] Following Dryer (2018), I use these terms as semantic notions. The NP elements are cross-linguistically instantiated in various syntactic constructions, but this is not relevant here.

2020b), and the postnominal modifier bias for a few elements of the NP (Do et al., 2022; Holtz et al., 2022), but has not addressed if and how this latter bias causes the frequency difference among the two isomorphic orders. In addition, the grammatical status of gesture experiments (Langus & Nespor, 2010), and hence their suitability as modality-specificity measures, is controversial. To overcome these limitations, the current research taught participants with no background in sign languages a novel sign system.
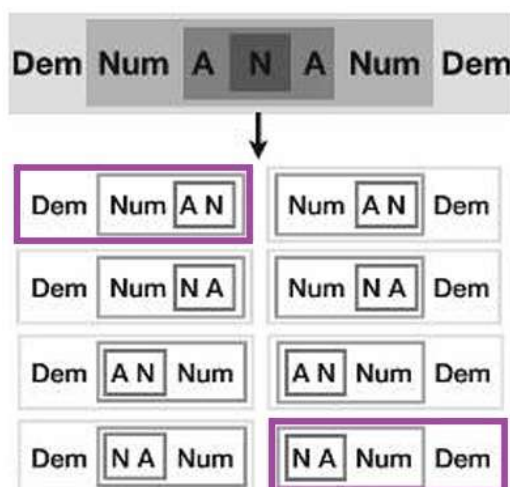
The present study asks whether there is a difference in cognitive processing load of a head-initial or head-final isomorphic complex noun phrase in a newly learned sign system. It is hypothesised that there is a smaller cognitive processing load for a head-initial isomorphic complex phrase as reflected by a lower reaction time in a phrase-picture matching task. Participants were native speakers of Dutch, which uses the head-final isomorphic order. This difference between the hypothesised cognitively preferred and native order allows to separate a cognitive preference from the automated, native order. In the following, Section 2 describes the typological word order patterns in a complex noun phrase across languages and modalities and how these are underpinned by an interplay of three cognitive biases. The methods and results are presented in Section 3 and 4, respectively. Section 5 discusses the findings.

2 Nominal word order preferences

When an NP consists of a noun, adjective, cardinal numeral and demonstrative, there are twenty-four possible orders in which these elements can be positioned. When an order can be created by first compounding the noun with the adjective and consecutively adding the numeral and demonstrative to the unit, it is said to be homomorphic (Culbertson et al., 2020b). In this way, because the adjective is closest to the noun and the demonstrative is the farthest, there is a straightforward mapping between the linearised order and its abstract representation (for details, see Section 2.2.1) (Culbertson, 2024). Of the twenty-four possibilities, eight orders are homomorphic (Figure 1). Importantly, the six head-central orders are only compatible with the notion of homomorphism, as they might well be merged in a different sequence (Culbertson et al., 2020b). For instance, Dem-A-N-Num can be created homomorphically, but the non-homomorphic alternative under which the noun and numeral were united first cannot be ruled out. The term isomorphic is thus reserved for the two homomorphic orders that are unambiguously homomorphic, namely the two orders of which all modifiers are positioned either prenominally or postnominally, also referred to as head-final or head-initial, respectively (Figure 1) (Culbertson et al., 2020b). Of note is that this distinction was not yet established in older literature that labels homomorphic orders as isomorphic. Head-final and head-initial orders, where all modifiers are on one side of the noun, are termed harmonic and should not be confused with isomorphism (Culbertson et al., 2020b). There are harmonic, non-homomorphic orders, such as N-Num-A-Dem, but there are no isomorphic, non-homomorphic orders, as isomorphism is by definition a subset of homomorphism.

Figure 1

Merging of the eight homomorphic and two isomorphic orders

Note. Highlighted in purple are the isomorphic orders, which are harmonic homomorphic orders. Figure from Culbertson et al. (2020b, p. 697), highlights are mine.

In the next two subsections, I discuss the typological patterns regarding the order of elements within the NP across modalities (Section 2.1) and the cognitive explanations that have been posited to account for these (Section 2.2).

2.1 Typological patterns

As sign languages employ a different modality than spoken languages, this allows for typological modality effects. Typological patterns can be similar across modalities, or they can diverge as a result of the affordances of each modality. This divergence can either be a relative or absolute modality effect, depending on whether the pattern differs in frequency between modalities or is unattested in one, respectively (Zeshan & Palfreyman, 2020). Possible sources of modality effects are the different articulators, perceptual systems, potential for iconicity and historical and demographic factors, such as the relative youth of sign languages (Meier, 2002). The latter source can be viewed as an indirect modality effect as it is not based on modality affordances (Zeshan & Palfreyman, 2020). An example of a relative modality effect with its source in the articulators is how simultaneous marking is easily possible in sign languages, but much less so in linear spoken languages. Additionally, as signing might be relatively slower than speaking, sign languages may prefer simultaneous nonconcatenative morphology, such as changing the root, while spoken languages prefer concatenative morphology, which adds morphemes sequentially (Meier, 2002). Therefore, this subsection explores the typological patterns in NP order across modalities.

2.1.1 Spoken languages

As for the individual elements within the NP, the World Atlas of Language Structures (WALS) reports cross-linguistic tendencies to order the adjective and cardinal numeral after the noun (Dryer, 2013a, 2013c). Of the languages in WALS that use a separate demonstrative word, a small majority also positions the demonstrative after the noun (Dryer, 2013b). When these four elements are combined in a complex noun phrase, there are twenty-four possible orders (Figure

2). However, only eighteen of these twenty-four orders are attested (Dryer, 2018). According to Greenberg's Universal 20 (1963), the most frequent word orders in a complex NP are Dem-Num-A-N, N-A-Num-Dem and N-Dem-Num-A. Yet, Cinque (2005) observed that, while the dominance of the head-final order holds, there is more variation in head-initial orders. In addition, head-central orders were among the then fourteen attested orders. More recently, eighteen orders were attested in a typological study by Dryer (2018). This study investigated the frequency of the possible word orders while correcting for language families and geographical distance. The resulting frequency distribution is skewed, with the first five most frequent word orders being homomorphic (Figure 2).

Figure 2

Cross-linguistic frequency distribution of the twenty-four possible word orders

Note. Homomorphic orders are highlighted in blue. Figure from Culbertson (2024, p. 364), data based on Dryer (2018).

Among the five most frequent orders, there is an additional skewed frequency distribution towards the isomorphic orders, where the modifiers are all positioned either postnominally or prenominally (the two leftmost orders in Figure 2) (Culbertson et al., 2020b). Within the additional skew towards isomorphism, there is a third skew towards the head-initial isomorphic order N-A-Num-Dem. An example of this most frequent order can be found in Mauwake:

(1) *mera   sia   maala erup nain*
    fish   net   long   two   that1
    N   N   A   Num   dem
    'the/those two long fish nets'   (adapted from Berghäll (2015, p. 231))

Whereas both English and Dutch use the head-final isomorphic Dem-Num-A-N: *those two long fish nets*. In sum, a complex NP with three modifiers has twenty-four possible orders, but

homomorphic and isomorphic orders are most frequent in spoken languages, in particular the head-initial isomorphic order.

<u>2.1.2 Sign languages</u>

The typological literature on NP order in sign languages is more limited, but the research thus far seems to support the patterns discussed above.

Firstly, Coons (2022) performed a study comparing data from 41 sign languages on orders with a noun and one modifier, including adjectives, numerals and demonstratives. As for the adjective, the tendency is for the adjective to be placed postnominally (39%) instead of prenominally (24.4%). However, contrasted with spoken language data from WALS, where 64% of languages position the adjective postnominally, this tendency seems to be less strong, presumably because there are relatively more sign languages (34.1%) than spoken languages (8%) that allow adjectives to be either postnominal or prenominal. Similarly, relatively more sign languages (27.8%) than spoken languages (5%) allow the numeral to be positioned both postnominally and prenominally. More sign languages place the numeral prenominally (41.7%) than postnominally (30.6%), but the proportion of spoken languages employing prenominal numerals is similar (42%). Hence, the discrepancy in typological frequency could be attributed to the number of sign languages without a dominant order. This also seems to be the case for pairings of a noun and a demonstrative. Whereas a small majority of spoken languages positions the demonstrative postnominally (45.8%), this flips for sign languages, where the majority positions the demonstrative prenominally (33.3%) rather than postnominally (27.8%), and, again, a substantial 30.6% does not have a dominant order. Thus, the tendency of spoken languages to position modifiers postnominally only clearly holds in sign languages for adjectives. However, considering the limitations in identifying order dominance (Coons, 2022), it is uncertain whether the opposite tendencies in sign languages for numerals and demonstratives are in fact modality effects.

Studies focusing on NP orders with multiple modifiers are limited to individual sign languages, but these findings do comply with the patterns identified in spoken languages. For example, Zhang (2007) investigated whether Taiwan Sign Language follows Greenberg's Universal 20 and concluded that it does. However, there is no clear pattern towards harmony or head position. In an NP with four elements, demonstratives position only prenominally, but numerals and adjectives can occur on either side. There is also no clear dominance of head-initial or head-final NPs. A similar flexibility emerges for Italian Sign Language. Brunelli (2011) reports that the modifiers only occur postnominally, but they do vary in ordering in this position. The dominant NP order is the isomorphic N-A-Num-Dem order, but the numeral and adjective can switch, which results in N-Num-A-Dem, an order that is not homomorphic. Mantovan and Geraci (2017) do report prenominal modifiers and state that the homomorphic Num-N-A-Dem is also prevalent. Even more orders were attested, such as (infrequent) repetition of the modifier, see example 2 (Mantovan & Geraci, 2017).

    (2) ANOTHER   JOB   ANOTHER
       A   N   A
       'another job'   (adapted from Mantovan & Geraci (2017, p. 194))

This variety is also observed in Dutch Sign Language (NGT), American Sign Language (ASL) and Polish Sign Language. In NGT, modifiers can occur on both sides of the noun and only demonstratives seem to more often occupy a prenominal position (Brunelli, 2011). When multiple modifiers are present prenominally, they order isomorphically (Brunelli, 2011). In ASL, adjectives can occur on both sides of the noun, but prenominally the dominant order is the isomorphic Dem-Num-A-N (Neidle & Nash, 2012). Some numerals undergo numeral incorporation by combining with a noun to form a new sign. In Polish Sign Language, the adjective usually follows the noun, while other modifiers normally precede it, which would amount to Dem-Num-N-A being dominant (Rutkowski et al., 2015). An example of this order can also be found in Mexican Sign Language, see example 3 (Coons, 2022).

(3) OTHER   ONE   CAT   GREY
     DEM   NUM   N   A
     'the other grey cat'   (adapted from Coons (2022, p. 10))

Thus, the literature for sign languages so far is in line with the patterns observed for spoken languages towards homomorphic and isomorphic orders. Sign languages seem to have more intralinguistic variation, but whether this flexibility is a modality effect or can be attributed to other factors remains to be determined.

2.2 Cognitive preferences

This subsection discusses how cognitive preferences for homomorphism, harmony and postnominal modifiers interplay to form a preference for a head-initial isomorphic NP. It is argued that two preferences are actually instantiations of one domain-general preference, namely the simplicity bias. According to the simplicity bias, if there are multiple hypotheses to explain data, learners prefer the simplest hypothesis, which is the one in which data is compressed most (Culbertson & Kirby, 2016).

2.2.1 Homomorphism

As mentioned, homomorphic orders are NP orders in which the adjective and noun are united first, followed by the numeral and demonstrative. The typological frequency of homomorphic orders can be cognitively explained by a semantic or conceptual perspective.

According to the semantic perspective, the adjective has scope over the noun, whereas the numeral and demonstrative have a bigger scope, as they scope over the combined meaning of the noun and modifier(s) (Culbertson, 2024). In this way, the linear homomorphic order represents the size of the semantic scope of each modifier.

From the conceptual perspective, a linear homomorphic order reflects the strength of association between an object and its properties. Demonstratives only provide contextual information, but numerals and adjectives can provide both contextual and property information. From these two, adjectives can signal the most property information and are thus most associated with the noun. These associations stem from non-linguistic conceptual knowledge (Culbertson, 2024). Homomorphism can then be considered a strategy to shorten the distance between those elements that provide the most information about the head (Culbertson et al.,

2020b). Both the semantic and conceptual perspective are compatible with the simplicity bias, as they explain the homomorphism preference as a transparent mapping between meaning and order (Culbertson & Kirby, 2016).

Evidence for a cognitive preference for homomorphism comes from artificial language learning experiments. In these experiments, participants typically start learning nouns by coupling these to visual stimuli (Martin et al., 2020). They then implicitly learn noun-modifier combinations. After this learning phase, they are asked to choose between two descriptions to match a picture. These descriptions contain structures that have not been encountered in the learning phase, namely a noun and two modifiers. Furthermore, they differ in that one description is homomorphic (in this case, N-A-Dem), and the other is non-homomorphic (N-Dem-A). Participants extrapolate towards homomorphic orders in experiments under various conditions, for example when the artificial language is presented orthographically, when the language is presented orally and they produce translations orally (Martin et al., 2020) and when their native language is non-homomorphic (Martin et al., 2024). This latter result especially provides evidence for a cognitive preference towards homomorphism, because participants did not transfer the non-homomorphic order of their native language, in this case N-Dem-Num-A from Kîîtharaka.

The artificial language experiments do not distinguish between the semantic and conceptual perspective. Evidence for the conceptual perspective comes from a study employing the silent gesture paradigm (Culbertson et al., 2020b). In this paradigm, participants without knowledge of any sign language communicate by gesturing. Participants were asked to describe images they saw on iPads close or far away. Images contained objects differing in shape, pattern, size and number. Participants strongly preferred homomorphic gesture orders, which is evidence for the conceptual perspective as there was no syntax to guide the gestures. In addition, the preference was weaker when size instead of pattern was gestured. In other words, the preference weakened when the communicated information was more context than property associated. In these cases, number instead of size was more closely ordered with the object.

In short, it seems that homomorphism can be cognitively explained. From both the semantic and conceptual perspective it would follow that this cognitive preference is amodal.

2.2.2. Isomorphism

Recall that isomorphism refers to the two homomorphic orders that are unambiguously homomorphic, namely the two harmonic orders. The additional typological skew towards isomorphism can then be explained as the combined preferences for homomorphism and harmony (Culbertson et al., 2020b). I will use the term harmony in the way it is often applied, namely as the consistent placement of modifiers relative to the head. Harmony is an instantiation of the simplicity bias, because positioning modifiers either prenominal or postnominal across phrases is simpler than specifying this for each phrase type (Culbertson & Kirby, 2016). The preference can be further interpreted as a general bias to group similar categories together (Culbertson, 2024).

Harmony can also be cognitively explained by the principle of predictability maximisation. According to this principle, depending on the to-be-predicted target, the head

should be either initial or final to increase the predictability of the modifiers or head, respectively (Ferrer-i-Cancho, 2025). The principle of syntactic dependency distance minimisation is an opposing force to place the head in the centre of the phrase to shorten the distance between individual modifiers and the head, but less relevant when the demand on working memory is small, for example for shorter sequences. So, for an individual NP, predictability maximisation is the only relevant principle, and it predicts harmony.

Evidence that harmony in the NP stems from a cognitive preference is also provided by artificial language learning experiments. In these, participants first learn nouns and noun-modifier combinations. Modifiers can occur on either side of the noun, but the ordering varies. Variation tends to be either dominantly harmonic (N-A, N-Num or A-N, Num-N) or non-harmonic (A-N, N-Num or N-A, Num-N) (Culbertson et al., 2020a). After the learning phase, participants produce noun-modifier combinations. Thus, instead of extrapolating to multiple modifiers, participants regularise the dominant frequency pattern of the variation they encountered in the learning phase. It was expected that learners regularise variation with predominantly harmonic orders more than variation with predominantly non-harmonic orders. In other words, it is easier to regularise a harmonic pattern, because it is cognitively preferred. This was indeed what has been found, both for English speakers (Culbertson et al., 2012) and speakers of non-harmonic languages, including French (Culbertson et al., 2020a). Additionally, the most used regularised orders were harmonic, because some participants in the non-harmonic conditions regularised towards non-input harmony (Culbertson et al., 2020a).

Recall that harmony can be viewed as a domain-general bias to group similar things together. Evidence for this perspective comes from two studies. In the first, Culbertson and Kirby (2022) set up two experiments in which participants learned to connect non-linguistic 'heads', and 'modifiers'. Stimuli were letter strings or shapes, and heads were longer strings or bigger shapes than modifiers. The ordering could be harmonic or non-harmonic, across or within heads. Across heads, this implies that the modifier is either prenominal or postnominal depending on the head (i.e., the type of phrase). For within heads, this means individual modifiers can be prenominal or postnominal. Thus, the harmonic ordering showed the least variation and the non-harmonic ordering within heads the most. After the learning phase, participants chose between two orders of which one matched with what they had learned (the correct one was a repetition from the learning phase). For both type of stimuli, accuracy increased as variation decreased, indicating that the harmony bias holds for non-linguistic stimuli and stems from a general simplicity bias (Culbertson & Kirby, 2022). In the second study, participants learned a harmonic word order in the verb phrase and were asked to produce an NP, which tests harmony across heads (Wang et al., 2025). By manipulating semantic similarity, they found that harmony was extrapolated more when adjectives were more like verbs than when they were not. This further indicates that harmony is based on simple similarity arrangements.

In sum, there is evidence that the skew towards isomorphism stems from a cognitive preference for harmony. The nature of this preference is to be determined, but both discussed accounts would predict that the preference is amodal.

2.2.3 Postnominal modifiers

The final cognitive preference causes the skew between the isomorphic orders by preferring modifiers to position postnominally[2]. As discussed, this pattern is typologically strongest for adjectives and the least strong for demonstratives. On the nature of the postnominal preference is less consensus than for the other preferences.

One cognitive explanation is that there is a preference to first communicate the concept and then its properties (Culbertson et al., 2020a). This means the modifier is easier to interpret, because the meaning of prenominal modifiers should be held in working memory before interpretation with the noun (Culbertson et al., 2020a). As for adjectives, postnominal position is advantageous in semantic processing, because the meaning of an adjective, for example the size of 'big', depends on its noun (Jaffan et al., 2020). Notice that this predicts that contextual adjectives would be subject to a greater extent to this preference than property adjectives (Jaffan et al., 2020), which is opposite from what is found for the homomorphism preference (Culbertson et al., 2020b). Culbertson & Kirby (2016) do not mention the postnominal preference in their discussion of the simplicity bias, but I argue this explanation could be an instantiation of the simplicity bias given that postnominal modifiers are a more straightforward mapping of meaning relations between the head and its modifiers to linear order.

Moreover, nouns are generally more inherently informative than modifiers. In a computational model with Bayesian agents, the less informative a modifier was compared to the noun, the more probable it was to position postnominally (Yu et al., 2023). This was also the case when the noun was contextually more informative than the adjective. When the adjective had more potential than the noun to disambiguate the referent, it was more probable to be prenominal. These tendencies perpetuated in iterated language learning. From a production perspective, these results can be seen as a pragmatic bias to aid the interpreter, but from a comprehension perspective, the cognitive aspect is clearer, in that what is generally most informative and interpretable is processed first.

Another production perspective is that nouns are easier accessed from the mental lexicon and that this is the force driving the preference (Culbertson et al., 2020a; Yu et al., 2023). If this is the case, it could be expected to hold for comprehension as well.

According to the information theoretic approach of Ferrer-i-Cancho (2024), there is an asymmetry in predicting the head or its modifiers, where heads are more predictable. Then, the strategy that maximises predictability is to predict the head, from which it follows that head-final orders are optimal. However, it could be argued that it pays off more to predict modifiers and hence place the head first, which levels out the asymmetry in predictability of each element.

Evidence for the cognitive nature of the postnominal modifiers preference comes from several experiments. One is an artificial language learning experiment, targeted to investigate the homomorphism preference by extrapolation (Martin et al., 2019). It is in methodology similar to the experiments discussed in Section 2.2.1. In this case, English and Thai speakers learned the artificial language with modifier position mirrored from their native language, that

---

[2] One exception is the genitive, which prefers a prenominal position (Holtz et al., 2022), but this is outside the scope of this study.

is, postnominal for the English speakers and prenominal for the Thai speakers. It was expected that under these conditions the Thai participants would more strongly extrapolate towards homomorphism, because prenominal non-homomorphism orders are less typologically prevalent than postnominal non-homomorphism orders. This could be, because they violate two cognitive preferences instead of one. Thus, because the language learned by the English speakers satisfied the postnominal preference, they had more opportunity to violate the homomorphism preference. This was indeed what the results showed.

Evidence that the preference also manifests in the visual modality comes mainly from silent gesture experiments. Firstly, Jaffan et al. (2020) found that Arabic, English, Mandarin and Spanish speakers have a preference for postnominal modifiers. Moreover, this preference was weaker or absent for numerals, and within adjectives, contextual adjectives were more likely than property adjectives to position postnominally. This influence of adjective semantics has also been found in similar experiments, but with signers of ASL, where adjectives can occur on both sides of the noun (Rubio-Fernandez et al., 2022). Another gesture experiment also showed that the majority of adjectives was gestured postnominally (Schouwstra et al., 2017). However, two results do not fully align with the preference. The proportion of postnominal position was higher for property than for contextual adjectives, which is opposite to the results of Jaffan et al. (2020) and Rubio-Fernandez et al. (2022). And, even though the proportion of postnominal placement was higher for numerals than demonstratives, in line with typology, there was no postnominal majority for either of the two. A postnominal preference for numerals did arise in the silent gesture experiment of Li & Do (2025) when numbers were in the subitising range, meaning that the quantity is sufficiently low to recognise without counting.

More comprehension related is a forced-choice task by Holtz et al. (2022), in which participants watched two videos, each gesturing a noun and adjective, but differing in the order. They then chose the video they thought best described the accompanying picture. The majority of participants preferred videos with a postnominal adjective. In a similar design, participants regularised more towards dominant input when that input had postnominal instead of prenominal adjectives, indicating that this order was easier to learn (Do et al., 2022).
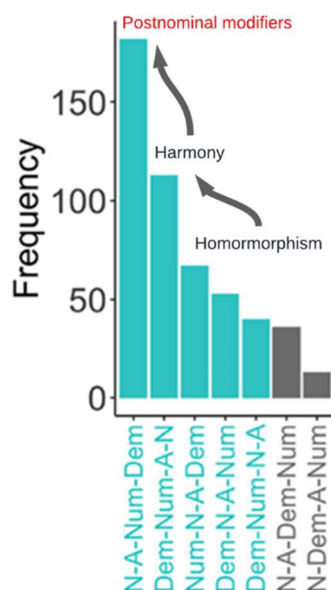
In short, postnominal modifiers can be cognitively explained as favourable. From all discussed accounts, it follows that the preference should be amodal.

2.3 The present study

In conclusion, three cognitive preferences (homomorphism, harmony and postnominal modifiers) are satisfied by the head-initial isomorphic NP, causing this order to be preferred (for a visual summary, see Figure 3).

Figure 3

Combination of cognitive preferences underlying the cross-linguistic frequency distribution of the seven most frequent orders in spoken languages

Note. The more cognitive preferences are satisfied by an order, the more it is preferred, which is in line with the typology. Homomorphic orders are highlighted in blue, the postnominal modifier preference is highlighted in red, as it is contrasted in the present study. Figure from Culbertson (2024, p. 364), data based on Dryer (2018), adaptations are mine.

Even though the nature of each preference is still debated, all theories predict the preferences to be amodal. However, evidence in the visual modality is mostly limited to gesture experiments with unknown linguistic status. Knowing if and how the preferences manifest in each modality can in turn inform theories on their nature. Thus, to gain insight into whether the cognitive preference for a head-initial isomorphic complex NP holds cross-modally, the present study investigates whether there is a difference in cognitive processing load of a head-initial or head-final isomorphic complex noun phrase in a newly learned sign system, hereby targeting the postnominal modifier preference.

An experiment was set up in which participants first learned a sign system and then performed a phrase-picture matching task. The experiment had a between-subjects design, in which two groups went through a learning and test phase. In the learning phase, each group learned a sign system consisting of 20 signs and performed a memory test. The systems differed in the sign order used to compose complex NPs. One group learned the system with head-initial isomorphic sign order (N-A-Num-Dem), henceforth group NAND, the other with head-final isomorphic sign order (Dem-Num-A-N), henceforth group DNAN. After the learning phase, the test phase consisted of a phrase-picture matching task in which reaction time was measured. In this way, reaction time serves as a proxy for cognitive load, and thus as a measure of a cognitive preference between the two sign orders.

3 Methods

3.1 Participants

47 native speakers of Dutch with no background in any sign language enrolled in the study. 46 participants (20 men, 26 women; mean age = 33.2 years; SD = 14.8) were included in the analysis, as one participant dropped out during the learning phase. Participants were recruited through a convenience sample and indicated to have normal or corrected-to-normal eyesight and no learning or language difficulties. Because age and gender are known to affect reaction time (Kosinski, 2008), people above the age of 60 were excluded from participation and participants were matched across groups in age (mean age difference = 2.7 years; SD = 3.0) and gender. No participants in the NAND group were familiar with a language with the same order. The experiment was approved by the Ethics Committee of the Faculty of Humanities of the University of Amsterdam and all participants gave informed consent (Appendix E).

3.2 Materials

For both the learning and test phase, the materials consisted of pictures and videos. The pictures were grey-scaled drawings taken from the Multilingual Picture (MultiPic) Database (Duñabeitia, 2025) and were further edited to fit the experiment. The videos showed signs or signed NPs. Signs were selected based on the chosen pictures. The signs and sign order of each group created two sign systems by which the NPs were formulated.

3.2.1 Sign selection and NP creation

The sign system contained 20 signs, of which 10 nouns, 4 adjectives, 5 numerals and 1 demonstrative (Appendix A). The first selection criterion was that the sign was iconic, because iconicity facilitates sign recognition and sign language processing more generally (Thompson, 2011). Iconicity of the signs was evaluated by the researcher and compound signs were excluded. The second criterion was that the sign was made at the height of the trunk to avoid face recognition in the videos. The nouns were selected based on the corresponding pictures that were chosen first. After the pictures and the corresponding noun signs had been selected, the adjective signs were chosen to contrast in size (BIG, SMALL) and location (UPPER, LOWER) between the chosen pictures. The numerals ranged from one till five, because the numeral systems in both NGT and ASL are one-handed, and as a result higher numbers are not iconic. The demonstrative was a pointing sign with extended index finger outward from the screen toward the viewer. Pointing to this arbitrary locus was opted for, because there were no demonstrative contrasts in the phrase-picture matching task. The signs were searched in an online dictionary for NGT (Nederlands Gebarencentrum, n.d.). If a sign did not meet the above-mentioned criteria or was not present in this dictionary, it was searched in a dictionary of ASL (Lapiak, n.d.). The signs for the location contrast (UPPER, LOWER) were newly created to include a disambiguating reference point (Figure A1-A3). As mentioned, the demonstrative was also not taken from a specific sign language.

After the individual signs had been chosen, 40 NPs were created, of which 5 example NPs, 10 NPs for the memory test and 25 for the phrase-picture matching task, including 5

practice trials. With the sign order manipulation this amounted to 80 NPs. The occurrence of each element was balanced within the memory test items, phrase-picture matching task items and across the example and practice items. For example, within the 20 NPs for the phrase-picture matching task, each noun occurred twice and each adjective and numeral five and four times, respectively. Moreover, for the NPs with a distractor picture, the occurrence of each element was balanced across distractor type, see the subsection below. No signs were inflected for plural use (e.g., by means of reduplication).

3.2.2 Pictures

Pictures (n=41) were used as stimuli in the memory test of the learning phase (see procedure) and as response options in the phrase-picture matching task. They were grey-scaled drawings taken from version 8 of the MultiPic Database (Duñabeitia, 2025). The MultiPic database has a collection of 500 picture drawings of objects with grey-scaled, black-and-white and coloured versions. In addition, it provides data on name agreement and familiarity for 35 languages. For Belgium and Netherlands Dutch only data on name agreement were available.

Pictures were selected from the database (n=10) if they showed an inanimate object, the Netherlands Dutch name agreement percentage was at least 80%, and the corresponding sign in either NGT or ASL was iconic and made at the height of the trunk. In addition, pictures were selected to form two categories with five pictures each. This resulted in a kitchen category, consisting of pictures of a glass, plate, knife, spoon and fork, and a transportation category, consisting of pictures of a car, bike, train, helicopter and airplane. To circumvent colour differences between the pictures, the grey-scaled versions were used, because the black-and-white versions were deemed less recognisable. After picture selection, pictures were edited in the GNU Image Manipulation Program (GIMP) (2024). Non-symmetric pictures were tilted or mirrored to face or point horizontally to the right side of the screen (Appendix B).

In the phrase-picture matching task, there were two pictures, a matching and non-matching picture, henceforth the distractor. The distractor contrasted in one element, either the noun, adjective or numeral (for examples, see Figures B3-B9). For half of the items, the distractor was a picture of a different object from the same category, but with equal number and size or location. For the other half of the items, the distractor differed equally in the adjective or numeral modifier. The distractor picture showed the same object, but in different quantity or with the opposite size or location. This was done to balance whether the head or modifiers had to predicted, as an interaction with sign order is expected (Ferrer-i-Cancho, 2024). Thus, pictures were edited to include up to five instances of the object. When there were two copies of an object, they were positioned side by side. A third copy was positioned triangularly on top of two copies. Four copies were positioned rectangularly. A fifth copy was added in the middle of the rectangle of four copies (Figure B2). Editing resulted in 41 pictures, as not every object was associated with all numerals in the stimuli NPs. Size and location of the pictures was instantiated by Experiment Designer, the program in which the experiment was implemented. Pictures were resized by a factor 1. For each item in the memory test, there were three distractors. At least one distractor differed in noun category, one in quantity and one distractor always matched the adjective in the NP. As there were ten items with four picture response

options each, every picture occurred once, except for a picture with five cars, which only occurred in a practice trial.

3.2.3 Videos

Videos (n=96) were recorded on a Samsung Galaxy S10 in which the researcher signed each NP. In frame was the neck and trunk of the researcher wearing a dark blue turtleneck jumper in front of a white background. This ensured a visible contrast between the hands and body. The face was not in frame to avoid distraction or surprisal as most participants knew the researcher, who is not a native signer, personally. Videos were edited with Microsoft Clipchamp. Audio was removed from each video. For the videos of the individual signs, the Dutch translation was written in the upper left corner of the frame. For the videos of the phrase-picture matching task, video duration and sign onset and offset was controlled. Video duration in seconds was controlled per item. For example, this meant that for a particular item, video duration was five seconds for both groups. Across all items, video duration ranged between four and six seconds. Sign onset and sign offset was defined as the time relative to video onset and video offset at which the hands were not yet or anymore in frame, respectively. Across items and groups, sign onset and sign offset was set to 0.5 seconds. This meant that for each video, the hands entered the frame 0.5 seconds after video onset and left the frame 0.5 seconds before video offset. This was not controlled for in the practice trials. In total there were 96 videos, of which 16 videos for the individual signs (counting from one till five was presented in one video), 10 videos for the 5 example NPs per group, 20 videos for the 10 memory test questions per group, 10 videos for the five practice trials and 40 videos with 20 items per group for the phrase-picture matching task.

3.3 Procedure

Both groups performed the same procedure, but differed in the sign order. One group learned the Dem-Num-A-N (DNAN) order, the other the N-A-Num-Dem (NAND) order. The experiment was an online survey implemented in Experiment Designer by the Speech Lab of the University of Amsterdam.

Each group started with a demographic questionnaire. The questionnaire asked for age, gender and language background. This was done to match participants and to exclude participants with a background in a sign language. Further information on language background was asked to assess whether participants in the NAND group had prior knowledge of a language with the same order.

The learning phase followed the questionnaire and was designed to enhance spacing of the presentation and repetition of sign meaning, as this is beneficial to vocabulary second language learning (Hulstijn, 2001). It started with four pages each containing five or six videos. The first pages showed the videos with the signs of the kitchen category (Figure B3), followed by the transportation category. The third page included the videos with the demonstrative, adjectives and numerals. These videos contained Dutch translations to ensure participants developed accurate meaning representations. The fourth page showed five non-translated examples of NPs to implicitly learn the sign order of the system. This also prevented awareness
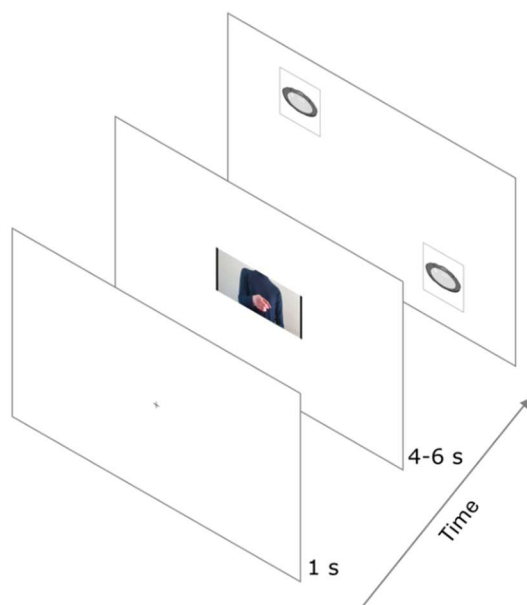
of order differences compared to Dutch in the NAND group. Every page instructed the participant to watch the videos in succession twice and to try to copy what was seen (for instructions, see Appendix D). This spaced meaning presentation and stimulated active learning and engagement with the materials. Additionally, practicing production aids comprehension in language learning (Hopman & MacDonald, 2018). Watching the videos of the individual signs in succession (N, Dem, A, Num) also ensured that there was no different homomorphic order implicitly present during the learning phase.

The learning phase continued with a randomised memory test of 10 items. Per item, participants watched a video and clicked the picture in a 2x2 matrix that matched the signed NP (Figure B4). It was possible to watch the video multiple times. Coupling NP meaning to a picture instead of a translation prevented awareness of order differences compared to Dutch in the NAND group. The memory test measured accuracy and served to exclude participants who did not sufficiently learn the sign system. It also permitted participants to strengthen NP comprehension and familiarise themselves with the pictures, as these were also present in the test phase. After completing the memory test, participants received the correct answers. They viewed each video with the correct matching picture in the same order as the memory test (Figure B5). Feedback aids vocabulary learning and learning in general (Metcalfe et al., 2009). Feedback was delayed (i.e., after completion of the test instead of after each item) to shorten the retention interval with the test phase, which also supports memory performance (Metcalfe et al., 2009). The learning phase concluded with rewatching the learned signs and example NPs once.

The test phase consisted of five practice and twenty test trials of a phrase-picture matching task. Each trial started with a fixation cross in the centre of the screen that was present for one second. Then, a video replaced the fixation cross. The video played once automatically. This was followed by two pictures on the left and right side of the screen at the same height as the video and fixation cross (except for trials with the location contrast) (Figure 4). If the left picture matched the video, participants selected this picture by pressing the 'e' key with their left index finger. If the right picture was a match, participants pressed the 'i' key with their right index finger. Trials were randomised as well as whether the correct picture was on the left or right side of the screen. Reaction time was measured from picture onset to picture selection.

Figure 4

Overview of a trial in the phrase-picture matching task

Note. First a fixation cross was visible for one second, followed by a video showing a signed NP (here the demonstrative sign is shown). Afterwards participants chose between the distracting and matching picture, here the location contrast for the practice trial NP THIS 1 UPPER PLATE/PLATE UPPER 1 THIS is shown.

3.4 Data analysis

Reaction time was measured for each trial in the test phase. After data collection, accuracy (1 for correct, 0 for incorrect) was determined by a technician of the Speech Lab of the University of Amsterdam for each trial based on the key pressed and the size, orientation and content of the pictures. Incorrect trials (n=35) were removed from the data. Except for the dropout participant, all participants scored above chance level on the memory test and test trials and were included in the analysis. Two outlier trials were removed from analysis, as reaction time was more than 5000 milliseconds. Results of the descriptive statistics were visualised using the ggplot2 package (Wickham, 2016). Normality of data was tested with a Shapiro-Wilk test. Data was analysed for a main effect of group and a main effect and interaction of item type on reaction time. Item type refers to head and modifier items. In head items, responses required decisions based on the head (object contrast), whereas for modifier items responses required decisions based on one of the modifiers, either the numeral (quantity contrast) or adjective (size or location contrast). For this inferential analysis, a generalised linear mixed-effects model was built in R 4.4.2 (R Core Team, 2024) and contrast coded for group (-0.5 for NAND, +0.5 for DNAN) and item type (-0.5 for head, +0.5 for modifier) using the lme4 package (Bates et al., 2015). The glmer function was used, because the data was positively skewed (Lo & Andrews, 2015). The model contained by-participant and by-item random intercepts. Based on the hypothesis a higher reaction time for the DNAN group was expected. Furthermore, an

interaction with item type was expected in which modifier items had a higher reaction time than head items for the DNAN group, as reflected by a positive slope in the model.

4 Results

4.1 Descriptive statistics

For the DNAN group, mean reaction time on the phrase-picture matching task was 1004.43 milliseconds (ms) (SD = 567.91). The NAND group had a mean reaction time of 1005.40 ms (SD = 427.14). Both groups were on average faster for items in which the distractor differed in the noun, thus when the head had to be predicted (DNAN = 936.21 ms, SD = 684.16; NAND = 962.91 ms, SD = 446.14) compared to trials in which the distractor differed in one of the modifiers, thus when either the adjective or the numeral had to be predicted (DNAN = 1119.24 ms, SD = 722.63; NAND = 1076.70 ms, SD = 576.64). For both groups, mean reaction time for head versus modifier items was 929.58 ms (SD = 395.31) and 1083.56 ms (SD = 583.37), respectively. These descriptive statistics are summarised in Table 1 and Figure 5 (for details, see Figure C1 and C2).
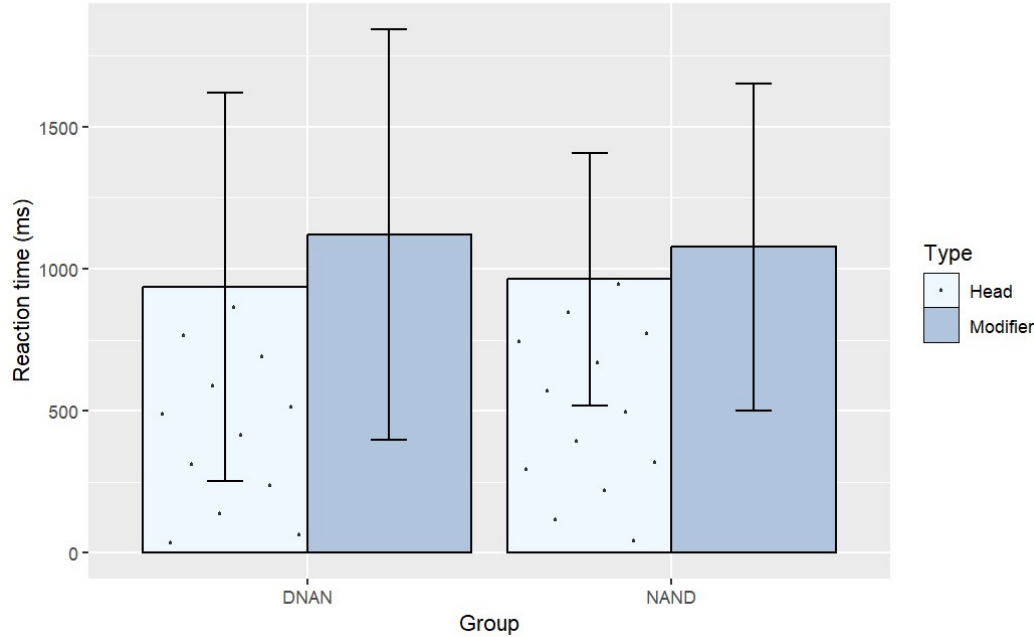
Table 1
Mean reaction times and standard deviations (SD) per group and item type

Group/Item type	Head	Modifier	Total
DNAN	936.21 ms (SD = 684.16)	1119.24 ms (SD = 722.63)	1004.43 ms (SD = 567.91
NAND	962.91 ms (SD = 446.14)	1076.70 ms (SD = 576.64)	1005.40 ms (SD = 427.14)
Total	929.58 ms (SD = 395.31)	1083.56 ms (SD = 583.37)	1004.91 ms (SD = 501.96)

Note. Means and standard deviations are in milliseconds and were calculated after removal of incorrect trials and outliers.

Figure 5

Mean reaction time per group and item type

Note. Error bars range in both directions one standard deviation from the mean. Means and standard deviations were calculated after removal of incorrect trials and outliers.

4.2 Inferential statistics

Data was non-normally distributed, as indicated by a Shapiro-Wilk test (W = 0.74, P-value < 2.2e-16). The generalised linear mixed-effects model estimated the slope of the interaction to be -39.67 ms, with a standard error of 53.64 ms, a P-value of 0.46 and a 95% confidence interval of [-144.81, 65.47]. Therefore, these results were non-significant. Since there was no interaction between group and item type, main effects of the individual predictors in the model were inspected. There was no significant main effect of group, with a slope of 19.84 ms, a standard error of 45.51 ms, a P-value of 0.66, a 95% confidence interval of [-69.36, 109.04]. However, the model estimated a significant main effect of item type, where responses to modifier items were on average an estimated 65 ms slower than to head items, with a slope of 64.72 ms, a standard error of 32.14 ms, a P-value of 0.04 and a 95% confidence interval of [1.72, 127.72]. Therefore, there was a significant main effect of item type, but no interaction with or main effect of group. These results are summarised in Table 2, for a further inspection of the main effect of item type, see Appendix C.

Table 2

Results of the generalised linear mixed-effects model per interaction and main effect

Effect	Estimate	SE	95% CI		P-value
			LB	**UB**	
Intercept	1143.23	40.96	1062.95	1223.51	<2e-16
Group:Item type	-39.67	53.64	-144.81	65.47	0.46
Group	19.84	45.51	-69.36	109.04	0.66
Item type	64.72	32.14	1.72	127.72	0.04

Note. Model estimations are in milliseconds. SE = standard error, CI = confidence interval, LB = lower bound, UB = upper bound.

5 Discussion

The aim of this study was to assess whether the cognitive preference in the auditory modality for a head-initial isomorphic complex NP also holds in the visual modality when a linguistic system is present. Current theories explain cross-linguistic NP tendencies as domain-general or language-specific cognitive preferences. From this it follows that these preferences should be amodal. It was thus hypothesised that the cognitive preference causing the skew between the isomorphic orders would manifest in the visual modality. To this end, two groups each learned a sign system, differing in sign order (Dem-Num-A-N or N-A-Num-Dem), and performed a phrase-picture matching task. Reaction time was measured as a proxy of cognitive load and thus cognitive preference. Accordingly, it was expected that the NAND group would be faster. However, results indicated no significant effect of group on reaction time. This suggests there was no difference in cognitive processing load between the sign orders. Yet, there was a significant main effect of item type on reaction time. Items in which the modifier was contrasted were answered an estimated 65 ms faster than items in which the head was contrasted. In spite of its hypothesis, this study thus failed to find a cognitive preference in the visual modality, interacting with item type, for the head-initial isomorphic complex NP. These results are incompatible with the cross-linguistic tendencies and cognitive preferences reported in various studies for the auditory and visual modality.

5.1 The effect of sign order group

As for the non-significant result of the interaction and main effect of group, five different interpretations can be drawn.

Firstly, failing to establish a link between sign order and reaction time could be attributed to a task effect. According to Yu et al. (2023), the cognitive preference for postnominal modifiers arises from the informativeness of nouns. However, it could be argued that in this task nouns and the modifiers adjectives and numerals were equally informative as they were the distracting element in an equal amount of trials. Another factor is adjective semantics. In Culbertson et al. (2020b), contextual adjectives were less associated with, and hence less closely gestured to, the noun as compared to property adjectives. Importantly, this

study examined the homomorphism preference and the predictions are opposite for the postnominal modifiers preference (Jaffan et al., 2020). However, the adjectives in the present study contrasted in contextual information, and it is possible that a weaker association with the noun weakened a placement preference relative to the noun. This weakening could potentially be enhanced by the lack of contrasting of the demonstrative, which left more contextual information to be carried by the other modifiers. As for numerals, quantities were in the subitising and counting range, whereas in Li & Do (2025) a postnominal preference only arose for the subitising range. In addition, a limitation in the design was that pictures appeared after video offset, meaning that the linguistic representation was already established. It is possible that this aspect of the design, combined with the varying video duration across items, tapped into working memory instead of linguistic processing. According to Ferrer-i-Cancho (2025), the principle of syntactic dependency distance minimisation is a stronger force when working memory demand is higher, i.e., there is more reason to preferably place the head in the centre of the phrase. As this was not the case for both groups, this could have obscured the preference.

A second interpretation of this result is that the cognitive preference did not manifest in reaction time, but possibly could surface in other outcome measurements. The studies discussed in Section 2 did find a cognitive preference, whether it was for homomorphism, harmony or postnominal modifiers, but none measured reaction time. Most studies measured (extrapolating) production preferences. It may be that the nature of the cognitive preferences is such that they manifest in production, but not in comprehension.

Similarly, the third explanation for the results is that the cognitive preference only manifests during, but not after, learning, meaning it would interplay with the presence of a linguistic system. While the discussed study of Holtz et al. (2022) found a preference for postnominal adjectives in gesture order, this preference disappeared when participants got input with a dominant ordering. Participants learned and consequently preferred the dominant order when choosing between two videos. Note, however, that Do et al. (2022) did find more regularisation when the input had dominantly postnominal than prenominal adjectives.

A fourth explanation for the results is that the nature of the cognitive preference for a head-initial isomorphic complex NP is modality-specific and does not manifest in the visual modality. If this were true, it would have implications for current theories on the cognitive preference, as these predict these preferences to be amodal and thus to also manifest in the visual modality. If this is not the case, the underlying cognitive bias might be biased in a different way than is currently theorised, causing it to be modality-specific.

The final interpretation discards cognitive preferences as the only explanation for cross-linguistic tendencies and instead posits an account which gives more importance to, for instance, cultural or diachronic factors (Culbertson, 2024; Evans & Levinson, 2009). Furthermore, there is evidence of a linguistic relativity effect of pre- or postnominal modifiers on information representation, speaking against the idea of a cognitive preference (Mata et al., 2014; Percy et al., 2009). However, this final interpretation is most speculative, as the absence of evidence in this study does not necessarily imply evidence of absence of the cognitive preference, for instance because of the reasons outlined above.

5.2 The effect of item type

As for the main effect of item type, this result is incompatible with the theory of Ferrer-i-Cancho (2025), according to which heads are generally more predictable than modifiers, but the head-initial isomorphic NP is optimal for predicting a modifier and the head-final isomorphic NP is optimal for predicting the head. Given this line of reasoning, it would be expected that item type interacts with group, causing the NAND group to be fast for both item types, but the DNAN group to be slower for modifier items. However, this is not what was found, namely a main effect of item type. This result only fits with the notion that heads are generally more predictable than modifiers, which for the present task is debatable, as all items contained an NP consisting of four elements, causing both types to be expected in every item.

Perhaps the conflicting result can be explained as a task effect. As mentioned, a possible working memory demand could have weakened the force of predictability maximisation (Ferrer-i-Cancho, 2025). Moreover, in four of the five items with a numeral distractor, the distractor differed only by one unit in quantity. Indeed, reaction time increases when the ratio between to-be-compared quantities is smaller (Barth et al., 2003). In the items with an adjective distractor, participants had to divert their gaze from the centre of the screen for the location contrast. Pictures from items with a noun contrast were also mapped on the screen according to location, so in both types of items, participants had to divert their gaze, but maybe more so for adjective location contrast items than for items with a noun contrast, as location was then equal for both pictures. It is possible that these modifier contrasts hindered participants in quickly spotting the matching picture despite understanding the NP. However, in a different task, a similar speed advantage has been found for items that focused on noun instead of adjective categorisation, suggesting nouns are more dominant in categorisation than adjectives (Percy et al., 2009). If this advantage extends to information representation more generally, this could explain the present finding on a more theoretical level.

5.3 Limitations and implications

Other limitations to be considered are the following. All participants were native speakers of Dutch, which employs the head-final isomorphic NP. It was expected that as a result of the cognitive preference, participants would prefer the non-native head-initial isomorphic NP, as native language orders are believed not to transfer in the silent gesture paradigm (Goldin-Meadow et al., 2008). However, transfer of both native and second language orders regarding post- or prenominal modifiers has been found in the artificial language learning study of Culbertson et al. (2020a), where participants regularised towards harmony. For example, French children regularised more towards a native postnominal order than adults with knowledge of English, who also regularised towards a prenominal order (Culbertson et al., 2020a). Perhaps language transfer occurred, because there was a linguistic system to map onto, meaning transfer would interplay with the linguistic status of the gestures or artificial language. This explanation may be incomplete, as language transfer also seemed to have occurred in the silent gesture task of Jaffan et al. (2020), where participants gestured towards a confederate with the same native language. For the present study, if language transfer occurred, this could mean that the DNAN group had an advantage that possibly obscured the cognitive preference. As for the design, a

further limitation is that it was not controlled for whether the perspective of a picture matched the perspective of an iconic sign, as this is known to affect reaction time in priming (McGarry et al., 2021). For example, the sign for 'bike' represents a frontal view of the pedals, which mismatches with the side view of the picture.

As previous studies employed production designs, the present study adds to the literature by focusing on cognitive load during comprehension. The results contrast with previous findings that did find a cognitive preference not only in the auditory, but also in the visual modality. This study found no difference in cognitive processing load between head-final and head-initial isomorphic complex NP sign orders. This does not comply with, and thus has implications for, current theories on the nature of the cognitive preference for postnominal modifiers, as this is the preference that is thought to cause the skew between the isomorphic orders.

Future research should therefore elucidate how the present results fit with the literature so far. For example, it should be tested whether the cognitive preference affects cognitive processing load in the auditory modality. The present design can be improved by a processing load measurement that is simultaneous with the stimuli, such as a self-paced reading task, which could also be adapted to signing. As the cognitive preference might only manifest in production, a production design with more linguistic status than a gesture experiment should be applied to the visual modality. Ideally, these experiments should examine the role of adjective semantics and include and compare participants with diverse native word orders learning unfamiliar orders. As for the sign system, it did not utilise commonalities of sign languages, such as simultaneous signing. It may be that there are additional cognitive preferences at play as to which signs and orders are suitable for this, for example in numeral incorporation. Future research should include these commonalities to further investigate how cognition interplays with the affordances of the modality.

References

Barth, H., Kanwisher, N., & Spelke, E. (2003). The construction of large number representations in adults. *Cognition, 86*(3), 201–221.

Bates, D., Maechler, M., Bolker, B., & Walker, S. (2015). Fitting linear mixed-effects models using lme4. *Journal of Statistical Software, 67*(1), 1–48.

Berghäll, L. (2015). *A grammar of Mauwake. (Studies in Diversity Linguistics 4).* Language Science Press.

Brunelli, M. (2011). *Antisymmetry and sign languages: A comparison between NGT and LIS.* PhD dissertation, University of Amsterdam. LOT.

Cinque, G. (2005). Deriving Greenberg's Universal 20 and its exceptions. *Linguistic Inquiry, 36*(3), 315–332.

Coons, C. (2022). Nominal word order typology in signed languages. *Frontiers in Communication, 6*, 802596.

Culbertson, J. (2024). Order shaped by cognition. Evidence for (and against) the effect of domain-general biases on word and morpheme order. *Zeitschrift für Sprachwissenschaft, 43*(2), 357–378.

Culbertson, J., Franck, J., Braquet, G., Navarro, M. B., & Arnon, I. (2020a). A learning bias for word order harmony: Evidence from speakers of non-harmonic languages. *Cognition, 204*, 104392.

Culbertson, J., & Kirby, S. (2016). Simplicity and specificity in language: Domain-general biases have domain-specific effects. *Frontiers in Psychology, 6*, 1964.

Culbertson, J., & Kirby, S. (2022). Syntactic harmony arises from a domain-general learning bias. *Proceedings of the Annual Meeting of the Cognitive Science Society, 44*(44).

Culbertson, J., Schouwstra, M., & Kirby, S. (2020b). From the world to word order: Deriving biases in noun phrase order from statistical properties of the world. *Language, 96*(3), 696–717.

Culbertson, J., Smolensky, P., & Legendre, G. (2012). Learning biases predict a word order universal. *Cognition, 122*(3), 306–329.

Do, M. L., Kirby, S., & Goldin-Meadow, S. (2022). Regularization of word order in the verb phrase differs from the noun phrase: Evidence from an online silent gesture perception paradigm. *Proceedings of the Annual Meeting of the Cognitive Science Society, 44*(44).

Dryer, M. S. (2013a). Order of adjective and noun. In Dryer, M. S. &. Haspelmath, M. (Ed.), *WALS Online (v2020.4)*.

Dryer, M. S. (2013b). Order of demonstrative and noun. In Dryer, M. S. &. Haspelmath, M. (Ed.), *WALS Online (v2020.4)*.

Dryer, M. S. (2013c). Order of numeral and noun. In Dryer, M. S. &. Haspelmath, M. (Ed.), *WALS Online (v2020.4)*.

Dryer, M. S. (2013d). Order of subject, object and verb. In Dryer, M. S. &. Haspelmath, M. (Ed.), *WALS Online (v2020.4)*.

Dryer, M. S. (2018). On the order of demonstrative, numeral, adjective, and noun. *Language, 94*(4), 798–833.

Duñabeitia, J. A. (2025). *MultiPic: Multilingual Picture Database (Version 8)*. figshare. https://doi.org/10.6084/m9.figshare.19328939.v8

Evans, N., & Levinson, S. C. (2009). The myth of language universals: Language diversity and its importance for cognitive science. *Behavioral and Brain Sciences, 32*(5), 429–448.

Ferrer-i-Cancho, R. (2024). Predictability maximization and the origins of word order harmony. *arXiv Preprint arXiv:2408.16570.*

Ferrer-i-Cancho, R. (2025). The optimal placement of the head in the noun phrase. The case of demonstrative, numeral, adjective and noun. *Journal of Quantitative Linguistics, 32*(1), 26–53.

Goldin-Meadow, S., So, W. C., Özyürek, A., & Mylander, C. (2008). The natural order of events: How speakers of different languages represent events nonverbally. *Proceedings of the National Academy of Sciences, 105*(27), 9163–9168.

Greenberg, J. H. (1963). Some universals of grammar with particular reference to the order of meaningful elements. In J. H. Greenberg (Ed.), *Universals of Language* (pp. 73–113). MIT Press.

Holtz, A., Kirby, S., & Culbertson, J. (2022). The influence of category-specific and system-wide preferences on cross-linguistic word order patterns. *Proceedings of the Annual Meeting of the Cognitive Science Society, 44*(44).

Hopman, E. W., & MacDonald, M. C. (2018). Production practice during language learning improves comprehension. *Psychological Science, 29*(6), 961–971.

Hulstijn, J. H. (2001). Intentional and incidental second language vocabulary learning: A reappraisal of elaboration, rehearsal and automaticity. In Robinson P. (Ed.), *Cognition and Second Language Instruction* (pp. 258-286). Cambridge University Press.

Jaffan, J., Klassen, G., Yang, J. Z., & Heller, D. (2020). Semantic influences on emergent preferences of word order: Evidence from silent gesture. *Proceedings of the Annual Meeting of the Cognitive Science Society, 42.*

Kosinski, R. J. (2008). A literature review on reaction time. *Clemson University, 10*(1), 337–344.

Langus, A., & Nespor, M. (2010). Cognitive systems struggling for word order. *Cognitive Psychology, 60*(4), 291–318.

Lapiak, J. (n.d.). *American Sign Language • ASL Dictionary.* HandSpeak. https://www.handspeak.com/word/

Li, C., & Do, M. L. (2025). From subitizing to approximation: Numeral processing effects on noun-number word order. Paper presented at the *38th Annual Conference on Human Sentence Processing,*

Lo, S., & Andrews, S. (2015). To transform or not to transform: using generalized linear mixed models to analyse reaction time data. *Frontiers in Psychology, 6 – 2015*.

Mantovan, L., & Geraci, C. (2017). The syntax of nominal modification in Italian Sign Language (LIS). *Sign Language & Linguistics, 20*(2), 183–220.

Martin, A., Adger, D., Abels, K., Kanampiu, P., & Culbertson, J. (2024). A universal cognitive bias in word order: Evidence from speakers whose language goes against it. *Psychological Science, 35*(3), 304–311.

Martin, A., Holtz, A., Abels, K., Adger, D., & Culbertson, J. (2020). Experimental evidence for the influence of structure and meaning on linear order in the noun phrase. *Glossa: A Journal of General Linguistics, 5*(1), 1–21.

Martin, A., Ratitamkul, T., Abels, K., Adger, D., & Culbertson, J. (2019). Cross-linguistic evidence for cognitive universals in the noun phrase. *Linguistics Vanguard, 5*(1), 20180072.

Mata, A., Percy, E. J., & Sherman, S. J. (2014). Adjective–noun order as representational structure: Native-language grammar influences perception of similarity and recognition memory. *Psychonomic Bulletin & Review, 21*, 193–197.

McGarry, M. E., Massa, N., Mott, M., Midgley, K. J., Holcomb, P. J., & Emmorey, K. (2021). Matching pictures and signs: An ERP study of the effects of iconic structural alignment in American Sign Language. *Neuropsychologia, 162*, 108051.

Meier, R. P. (2002). Why different, why the same? Explaining effects and non-effects of modality upon linguistic structure in sign and speech. In Meier, R. P., Cormier, K., & Quinto-Pozos, D. (Ed.), *Modality and Structure in Signed and Spoken Languages* (pp. 1–25). Cambridge University Press.

Metcalfe, J., Kornell, N., & Finn, B. (2009). Delayed versus immediate feedback in children's and adults' vocabulary learning. *Memory & Cognition, 37*(8), 1077–1087.

Napoli, D. J., & Sutton-Spence, R. (2014). Order of the major constituents in sign languages: Implications for all language. *Frontiers in Psychology, 5*, 376.

Nederlands Gebarencentrum. (n.d.). *Gebarenwoordenboek.* https://ow.gebarencentrum.nl/

Neidle, C., & Nash, J. (2012). 13. The noun phrase. In Pfau, R., Steinbach, M. & Woll, B. (Ed.), *Sign Language: An International Handbook* (pp. 265–292). De Gruyter Mouton.

Percy, E. J., Sherman, S. J., Garcia-Marques, L., Mata, A., & Garcia-Marques, T. (2009). Cognition and native-language grammar: The organizational role of adjective-noun word order in information representation. *Psychonomic Bulletin & Review, 16*, 1037–1042.

Perniss, P., Pfau, R., & Steinbach, M. (2007). Can't you see the difference? Sources of variation in sign language structure. In Perniss, P., Pfau, R. & Steinbach, M. (Ed.), *Visible Variation: Comparative Studies on Sign Language Structure* (pp. 1–34). Mouton de Gruyter.

R Core Team. (2024). *R: A Language and Environment for Statistical Computing.* R Foundation for Statistical Computing.

Rubio-Fernandez, P., Wienholz, A., Ballard, C. M., Kirby, S., & Lieberman, A. M. (2022). Adjective position and referential efficiency in American Sign Language: Effects of adjective semantics, sign type and age of sign exposure. *Journal of Memory and Language, 126*, 104348.

Rutkowski, P., Kuder, A., Czajkowska-Kisil, M., & Łacheta, J. (2015). The structure of nominal constructions in Polish Sign Language (PJM): A corpus-based study. *Studies in Polish Linguistics*, *10*(1), 1-15.

Sandler, W. (2013). Vive la différence: Sign language and spoken language in language evolution. *Language and Cognition, 5*(2-3), 189–203.

Schouwstra, M., Kirby, S., & Culbertson, J. (2017). Silent gesture and noun phrase universals. *Proceedings of the Annual Meeting of the Cognitive Science Society, 39.*

The GIMP Development Team. (2024). *GNU Image Manipulation Program (GIMP), Version 2.10.38. Community, Free Software (license GPLv3).*

Thompson, R. L. (2011). Iconicity in language processing and acquisition: What signed languages reveal. *Language and Linguistics Compass, 5*(9), 603–616.

Wang, F., Kirby, S., & Culbertson, J. (2025). The learning bias for cross-category harmony is sensitive to semantic similarity: Evidence from artificial language learning experiments. *Language, 101*(1), 109–150.

Wickham, H. (2016). *ggplot2: Elegant graphics for data analysis*. Springer-Verlag.

Wilson, V. A. D., Zuberbuhler, K., & Bickel, B. (2022). The evolutionary origins of syntax: Event cognition in nonhuman primates. *Science Advances, 8*(25), eabn8464.

Yu, D., Waldon, B., & Degen, J. (2023). The cross-linguistic order of adjectives and nouns may be the result of iterated pragmatic pressures on referential communication. *Proceedings of the Annual Meeting of the Cognitive Science Society, 45(45).*

Zeshan, U., & Palfreyman, N. (2020). Comparability of signed and spoken languages: Absolute and relative modality effects in cross-modal typology. *Linguistic Typology, 24*(3), 527–562.

Zhang, N. N. (2007). Universal 20 and Taiwan Sign Language. *Sign Language & Linguistics, 10*(1), 55–81.

Appendices

Appendix A: The sign system

Table A1

Overview of the twenty signs of the sign system and their source

Sign	Source
Noun (kitchen category)	
GLASS	ASL (sign for cup)
PLATE	NGT
KNIFE	NGT
FORK	NGT
SPOON	ASL
Noun (transportation category)	
CAR	NGT
BIKE	NGT
TRAIN	NGT
AIRPLANE	NGT
HELICOPTER	ASL
Numeral	
1	NGT
2	NGT
3	NGT
4	NGT
5	NGT
Adjective	
UPPER, UP	Newly created; non-dominant hand flat and palm down as a reference, dominant hand flat and palm down positioned above, after non-dominant hand is positioned (Figure A1)
LOWER, LOW	Newly created; non-dominant hand flat and palm down as a reference, dominant hand flat and palm down positioned under, after non-dominant hand is positioned (Figure A2)
BIG, LARGE	ASL
SMALL	ASL
Demonstrative	
THIS, THESE, THAT, THOSE	Pointing forward with the index finger of the dominant hand. For the viewer, the pointing is towards them (Figure A3)

Figure A1

Final position of the sign UPPER, UP

Figure A2

Final position of the sign LOWER, LOW

Figure A3

The demonstrative sign THIS, THESE, THAT, THOSE

Table A2

Overview of the five signed example NPs for each group Participants viewed the NPs without translation to implicitly learn the sign order of the NP.

Dem-Num-A-N (DNAN)	N-A-Num-Dem (NAND)
THIS 1 UPPER GLASS	GLASS UPPER 1 THIS
THESE 2 BIG BIKES	BIKES BIG 2 THESE
THESE 3 SMALL FORKS	FORKS SMALL 3 THESE
THESE 4 SMALL HELICOPTERS	HELICOPTERS SMALL 4 THESE
THESE 5 LOWER AIRPLANES	AIRPLANES LOWER 5 THESE

Table A3

Overview of the ten signed NPs and their distractors in the memory test for each group

Distractor 1	Distractor 2	Distractor 3	Dem-Num-A-N (DNAN)	N-A-Num-Dem (NAND)
Helicopter	Two small airplanes	Three spoons	THIS 1 SMALL PLATE	PLATE SMALL 1 THIS
Four knifes	Two big bikes	Three forks	THESE 2 BIG GLASSES	GLASSES BIG 2 THESE
Two plates	Four small helicopters	Bike	THESE 3 SMALL SPOONS	SPOONS SMALL 3 THESE
Two trains	Three upper cars	Glass	THESE 4 UPPER FORKS	FORKS UPPER 4 THESE
Four airplanes	Two lower forks	Three plates	THESE 5 LOWER KNIFES	KNIFES LOWER 5 THESE
Four bikes	Two lower spoons	Three glasses	THIS 1 LOWER TRAIN	TRAIN LOWER 1 THIS
Car	Five upper helicopters	Four trains	THESE 2 UPPER AIRPLANES	AIRPLANES UPPER 2 THESE
Two cars	Four lower glasses	Five spoons	THESE 3 LOWER HELICOPTERS	HELICOPTERS LOWER 3 THESE
Knife	Three small bikes	Spoon	THESE 4 SMALL CARS	CARS SMALL 4 THESE
Three airplanes	Four big spoons	Airplane	THESE 5 BIG BIKES	BIKES BIG 5 THESE

Note. Distractor refers to the element that differed in the non-matching picture. Distractor 2 corresponded with the adjective in the NP.

Table A4

Overview of the five signed NPs for the practice trials in the test phase

Distractor	Sign order	
	Dem-Num-A-N (DNAN)	N-A-Num-Dem (NAND)
Lower	THIS 1 UPPER PLATE	PLATE UPPER 1 THIS
Bike	THESE 2 BIG TRAINS	TRAINS BIG 2 THESE
2	THESE 3 LOWER SPOONS	SPOONS LOWER 3 THESE
Fork	THESE 4 SMALL KNIFES	KNIFES SMALL 4 THESE
Small	THESE 5 BIG CARS	CARS BIG 5 THESE

Note. Distractor refers to the element that differed in the non-matching picture.

Table A5

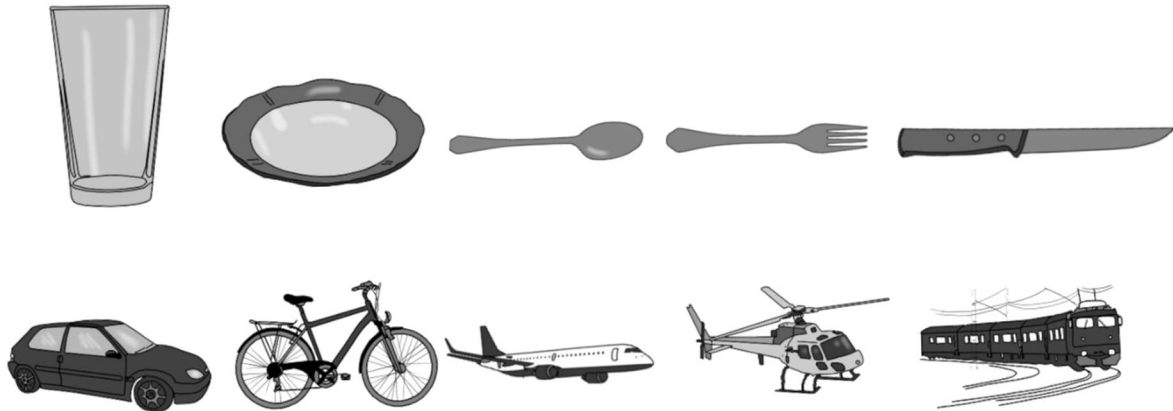*The 20 signed NPs for each group in the test phase*

Distractor	Sign order	
Noun from transportation category	*Dem-Num-A-N (DNAN)*	*N-A-Num-Dem (NAND)*
Airplane	THIS 1 UPPER HELICOPTER	HELICOPTER UPPER 1 THIS
Car	THESE 2 LOWER AIRPLANES	AIRPLANES LOWER 2 THESE
Bike	THESE 3 UPPER CARS	CARS UPPER 3 THESE
Train	THESE 4 BIG BIKES	BIKES BIG 4 THESE
Helicopter	THESE 5 SMALL TRAINS	TRAINS SMALL 5 THESE
Noun from kitchen category		
Plate	THIS 1 LOWER GLASS	GLASS LOWER 1 THIS
Spoon	THESE 2 UPPER FORKS	FORKS UPPER 2 THESE
Fork	THESE 3 SMALL PLATES	PLATES SMALL 3 THESE
Glass	THESE 4 BIG KNIFES	KNIFES BIG 4 THESE
Knife	THESE 5 SMALL SPOONS	SPOONS SMALL 5 THESE
Numeral		
2	THIS 1 BIG PLATE	PLATE BIG 1 THIS
3	THESE 2 BIG FORKS	FORKS BIG 2 THESE
4	THESE 3 UPPER AIRPLANES	AIRPLANES UPPER 3 THESE
5	THESE 4 LOWER SPOONS	SPOONS LOWER 4 THESE
1	THESE 5 LOWER BIKES	BIKES LOWER 5 THESE
Adjective		
Big	THIS 1 SMALL KNIFE	KNIFE SMALL 1 THIS
Big	THESE 2 SMALL CARS	CARS SMALL 2 THESE
Small	THESE 3 BIG GLASSES	GLASSES BIG 3 THESE
Upper	THESE 4 LOWER HELICOPTERS	HELICOPTERS LOWER 4 THESE
Lower	THESE 5 UPPER TRAINS	TRAINS UPPER 5 THESE

Note. Distractor refers to the element that differed in the non-matching picture. A distractor could differ in one element at a time in location (upper/lower side of the screen), size (bigger/smaller) and number (amount of objects, range between one and five). Per sign order group, every noun appears in two NPs, one with a distractor differing in a noun from the same category, one with a distractor differing in modifier, either numeral or adjective. Every numeral appears four times and every adjective appears five times across the distractor conditions.

Figure B1
Overview of the ten edited pictures

Note. Upper row: kitchen category, from left to right: glass, plate, spoon, fork and knife. Lower row: transportation category, from left to right: car, bike, airplane, helicopter and train.

Figure B2
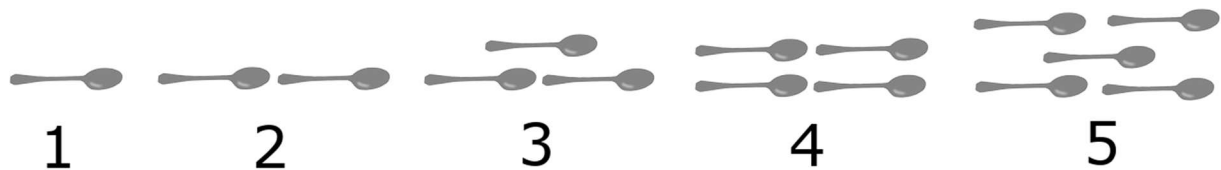*Example overview of how objects were positioned from 1 up to 5 instances of the object*
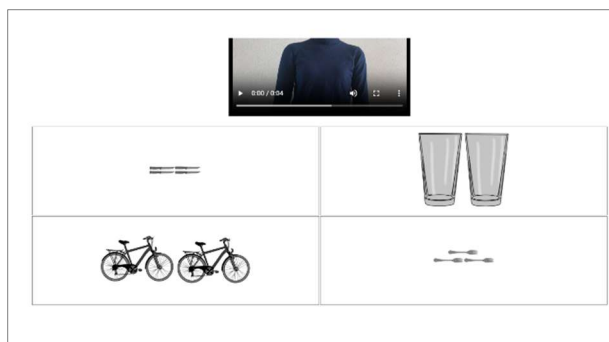

Figure B3
Example of the screen during the first part of the learning phase

Note. Here shown for the kitchen category.
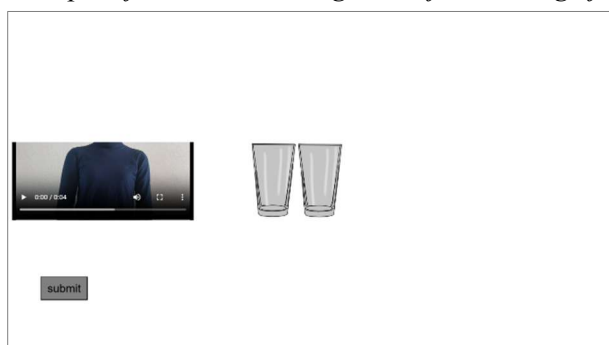
Figure B4

Example of the screen during the memory test

Note. Here shown for the NP THESE 2 BIG GLASSES/GLASSES BIG 2 THESE. Pictures were presented in a 2x2 matrix.
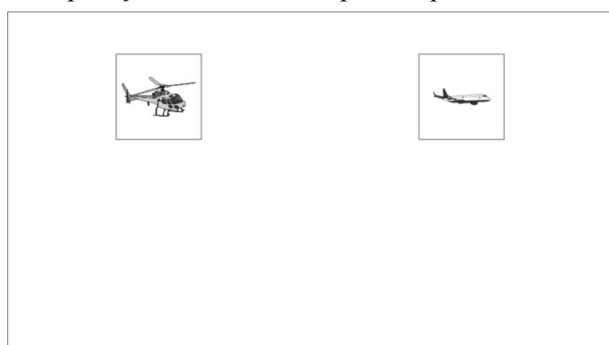
Figure B5

Example of the screen during the self-correcting of the memory test

Note. Here shown the answer for the NP THESE 2 BIG GLASSES/GLASSES BIG 2 THESE.

Figure B6

Example of the screen in the phrase-picture matching task with a noun contrast

Note. Here shown for the NP THIS 1 UPPER HELICOPTER/HELICOPTER UPPER 1 THIS.
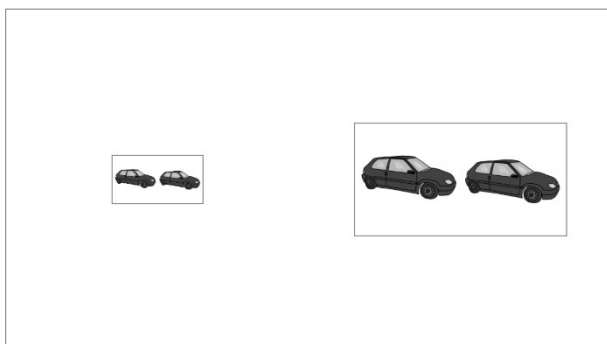
Figure B7

Example of the screen in the phrase-picture matching task with a numeral contrast

Note. Here shown for the practice NP THESE 3 LOWER SPOONS/SPOONS LOWER 3 THESE.
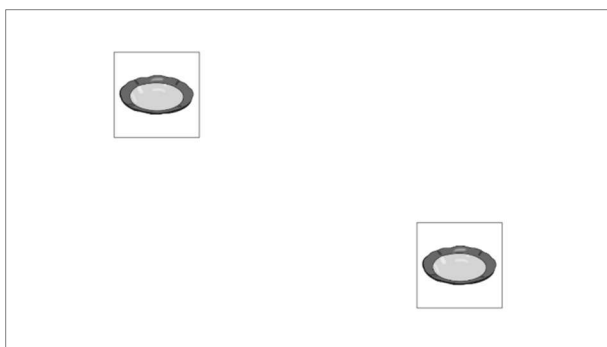
Figure B8

Example of the screen in the phrase-picture matching task with an adjective size contrast

Note. Here shown for the NP THESE 2 SMALL CARS/CARS SMALL 2 THESE.

Figure B9

Example of the screen in the phrase-picture matching task with an adjective location contrast
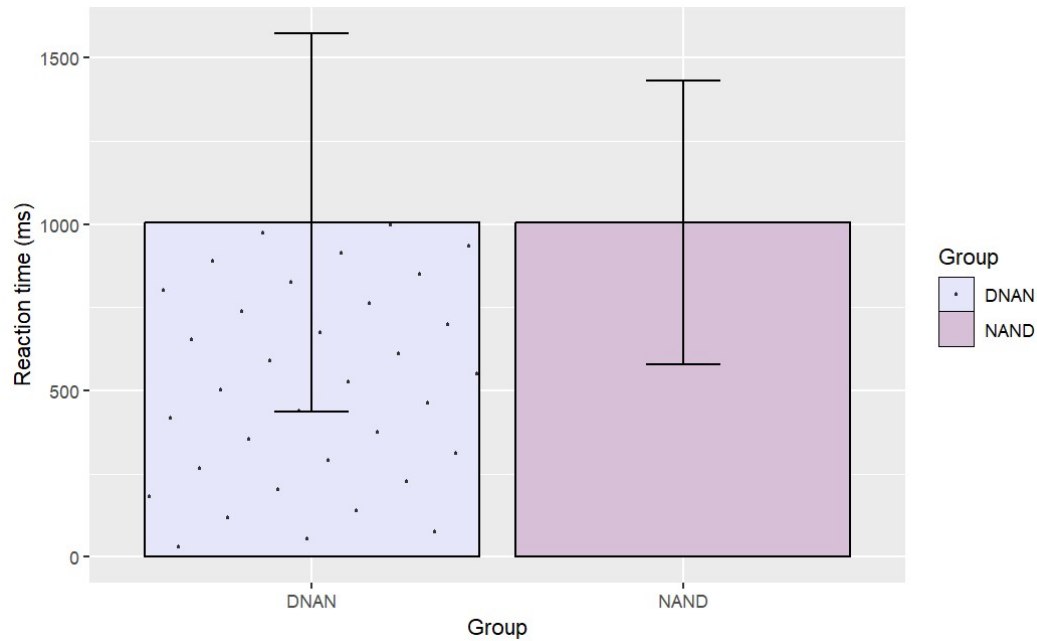

Note. Here shown for the practice NP THIS 1 UPPER PLATE/PLATE UPPER 1 THIS.

Descriptive statistics

Figure C1
Mean reaction time per group

Note. Error bars range in both directions one standard deviation from the mean. Means and standard deviations were calculated after removal of incorrect trials and outliers.
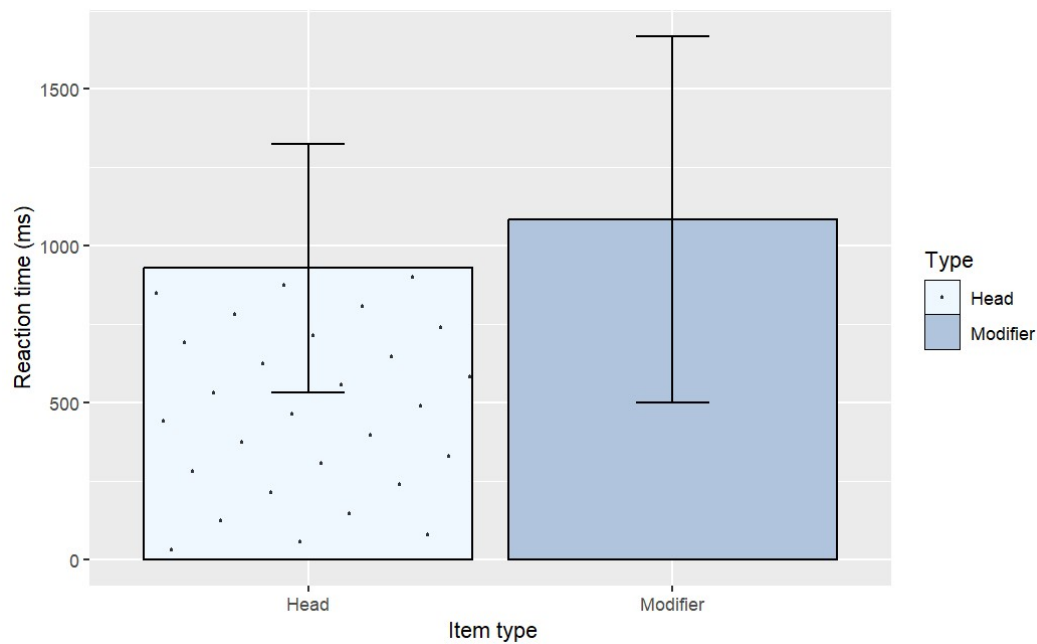
Figure C2
Mean reaction time per item type

Note. Error bars range in both directions one standard deviation from the mean. Means and standard deviations were calculated after removal of incorrect trials and outliers.

Because responses to modifier items had a significantly higher reaction time, a generalised linear mixed-effects model was built on only modifier items to see whether the effect was due to a specific modifier. The model contained by-participant and by-item random intercepts and was contrast-coded for group (-0.5 for NAND, +0.5 for DNAN) and modifier type (-0.5 for adjectives, +0.5 for numerals). The model predicted that reaction time for numerals was 69 ms higher than for adjectives, but there was no significant main effect of either group, modifier type or their interaction (Table C1).

Table C1

Results of the generalised linear mixed-effects model per each main effect or interaction.

Effect	Estimate	SE	95% CI		P-value
			LB	**UB**	
Intercept	1246.04	65.33	1118.01	1374.08	<2e-16
Group:Modifier type	25.26	93.89	-158.76	209.28	0.79
Group	109.68	78.09	-43.38	262.74	0.16
Modifier type	69.29	49.68	-28.08	166.67	0.16

Note. Model estimations are in milliseconds. SE = standard error, CI = confidence interval, LB = lower bound, UB = upper bound.

Algemene introductie

Dankuwel voor uw deelname aan dit onderzoek! Dit onderzoek bestaat uit één testmoment van ongeveer 30 minuten. Tijdens het onderzoek beantwoordt u eerst een aantal vragen, daarna gaat u gebaren en combinaties van gebaren leren. Tot slot vergelijkt u gebaarde zinnen met steeds twee plaatjes.

LET OP: Druk niet op Escape want dan wordt het programma beëindigd.

Druk op de spatiebalk om verder te gaan.

Instructie leerfase

U begint nu met het leren van de gebaren. Ook ziet u voorbeelden van combinaties van gebaren. Bekijkt u elke video tweemaal: Kijk eerst alle video's één keer en dan alle video's nog één keer. Probeer na elke keer kijken het gebaar of de combinatie van gebaren zelf na te doen. Als u hiermee klaar bent, kunt u door naar het volgende onderdeel.

Druk op de spatiebalk om verder te gaan.

Instructie tijdens leerfase

Bekijkt u elke video tweemaal: Kijk eerst alle video's één keer en dan alle video's nog één keer. Probeer na elke keer kijken het gebaar of de combinatie van gebaren zelf na te doen.

LET OP: Als u de video vergroot, druk dan rechtsonder op het vergroot/verklein icon om terug te gaan naar de normale grootte. Druk dus niet op Escape want dan wordt het programma meteen beëindigd.

Instructie geheugentest

Nu volgt een geheugentest over de geleerde gebaren en hoe ze gecombineerd kunnen worden. U krijgt een gebaarde zin te zien die een plaatje omschrijft, antwoord door het plaatje aan te klikken dat omschreven wordt.

Druk op de spatiebalk om verder te gaan.

Instructie na geheugentest

U krijgt nu de antwoorden van de geheugentest te zien, zodat u uzelf kunt nakijken.

Druk op de spatiebalk om verder te gaan.

Instructie na nakijken geheugentest

Bekijk elke video nog eenmaal.

LET OP: Als u de video vergroot, druk dan rechtsonder op het vergroot/verklein icon om terug te gaan naar de normale grootte. Druk dus niet op Escape want dan wordt het programma meteen beëindigd.

Druk op de spatiebalk om verder te gaan.

Instructie tijdens herhalen leerfase

Bekijk elke video nog eenmaal.

LET OP: Als u de video vergroot, druk dan rechtsonder op het vergroot/verklein icon om terug te gaan naar de normale grootte. Druk dus niet op Escape want dan wordt het programma meteen beëindigd.

Instructie testfase

Nu volgt een taak waarbij u gebaarde zinnen vergelijkt met steeds twee plaatjes. U bekijkt een video die in gebaren een plaatje omschrijft. Voor de video ziet u een kruis op het scherm, focus uw blik daarop. Na de video ziet u twee plaatjes. Aan u de taak om **zo snel mogelijk** te beoordelen welk plaatje door de video omschreven werd. Als dit het linkerplaatje is, drukt u met uw linkerwijsvinger op de 'e' toets op uw toetsenbord. Als dit het rechterplaatje is, drukt u met uw rechterwijsvinger op de 'i' toets op uw toetsenbord. Houd steeds uw linkerwijsvinger op de 'e' toets en uw rechterwijsvinger op de 'i' toets, zodat u zo snel mogelijk kunt reageren. Eerst zullen 5 oefenvragen volgen, daarna begint de echte taak.

Druk op de spatiebalk om verder te gaan.

Instructies na oefenvragen

Nu begint de echte taak. Houd steeds uw linkerwijsvinger op de 'e' toets en uw rechterwijsvinger op de 'i' toets, zodat u zo snel mogelijk kunt reageren.

Druk op de spatiebalk om verder te gaan.

Instructies na testfase

U bent nu klaar met het onderzoek. Hartelijk bedankt voor uw deelname!

LET OP: Druk niet op Escape, het programma sluit vanzelf.

English translation

General introduction

Thank you for participating in this study! This study consists of one test moment of about 30 minutes. During the study, you will first answer some questions, then you will learn signs and combinations of signs. Finally, you will compare signed phrases with two pictures each time.

NOTE: Do not press Escape because it will end the program.

Press the space bar to continue.

Instruction learning phase

You will now begin to learn the signs. You will also see examples of combinations of signs. Watch each video twice: First watch all videos once and then watch all videos one more time. After each viewing, try to imitate the sign or combination of signs yourself. When you are done with this, you can move on to the next section.

Press the space bar to continue.

Instruction during learning phase

Watch each video twice: First watch all videos once and then watch all videos once more. After each viewing, try to imitate the sign or combination of signs yourself.

NOTE: If you enlarge the video, press the enlarge/reduce icon at the bottom right to go back to normal size. Do not press Escape as this will immediately end the program.

Instruction memory test

Now follows a memory test on the sign learned and how they can be combined. You will be shown a signed sentence describing a picture, answer by clicking on the picture being described.

Press the space bar to continue.

Instruction after memory test

You will now be shown the answers from the memory test, so you can check yourself.

Press the space bar to continue.

Instruction after reviewing memory test

Watch each video one more time.

NOTE: If you enlarge the video, press the enlarge/reduce icon in the lower right corner to return to normal size. Do not press Escape as this will immediately terminate the program.

Press the space bar to continue.

Instruction test phase

Now follows a task in which you compare signed sentences with two pictures each time. You watch a video describing a picture with signs. Before the video you see a cross on the screen, focus your gaze on that. After the video you will see two pictures. Your task is to judge **as quickly as possible** which picture was described by the video. If this is the left image, press the 'e' key on your keyboard with your left index finger. If this is the right picture, press the 'i' key on your keyboard with your right index finger. Always keep your left index finger on the 'e' key and your right index finger on the 'i' key so that you can respond as quickly as possible. First, 5 practice questions will follow, then the real task begins.

Press the space bar to continue.

Instruction after practice trials

Now the real task begins. Always keep your left index finger on the 'e' key and your right index finger on the 'i' key so that you can respond as quickly as possible.

Press the space bar to continue.

Instruction after test phase

You have now finished the research. Thank you very much for your participation!

NOTE: Do not press Escape, the program will close by itself.

Information brochure (Dutch original)

Beste deelnemer,

U gaat deelnemen aan het onderzoek 'Het leren van gebaren en gebarencombinaties' van de Universiteit van Amsterdam, capaciteitsgroep Taalwetenschap, uitgevoerd door Sigrid Bruinsma onder begeleiding van dr. Roland Pfau. Voordat het onderzoek begint, is het belangrijk dat u kennis neemt van de procedures die in dit onderzoek worden gevolgd. Leest u deze brochure daarom zorgvuldig door.

Doel van het onderzoek

Dit onderzoek kijkt naar hoe ons denken invloed heeft op taal. Bijzonder aan mensen is dat we taal kunnen gebruiken met woorden én gebaren. Wij willen weten hoe mensen gebaren leren in een gebarentaal die ze nog niet kennen. Dit onderzoek helpt ons meer te weten over hoe mensen communiceren.

Waarom is dit onderzoek belangrijk?

•   We leren hoe talen werken

•   Het helpt ons begrijpen waarom talen verschillend zijn

Wie kan er aan dit onderzoek meedoen

Voor dit onderzoek worden volwassen moedertaalsprekers van het Nederlands tussen 16 en 60 jaar uitgenodigd. Gezien de aard van het onderzoek is het van belang dat u goed kunt zien. Het dragen van een bril of lenzen is wel mogelijk. Verder stellen wij u een aantal vragen over uw taalachtergrond. U kunt deelnemen aan dit onderzoek als Nederlands uw moedertaal is en u geen gebarentaal kent. Verder is het van belang dat u, voor zo ver bij u bekend, geen geheugenprobleem of taalprobleem heeft, zoals dyslexie of een specifieke taalstoornis.

Instructie en procedure

U beantwoordt eerst wat algemene vragen. Dan begint u met leren. U ziet gebaren en volgt een bepaalde procedure om ze te leren. Daarna doet u een taak om te kijken hoe het leerproces verlopen is. Hierin koppelt u gebaarde zinnen aan plaatjes. In totaal duurt het onderzoek 30 minuten.

Vrijwilligheid

U doet vrijwillig mee aan dit onderzoek. U kunt dan ook op elk moment gedurende het onderzoek uw deelname stopzetten. Dit zal geen gevolgen voor u hebben en u bent in geen geval verplicht de hierboven beschreven procedures af te ronden. Tevens kunt u na het onderzoek altijd besluiten uw toestemming alsnog in te trekken. Als u uw deelname staakt of toestemming intrekt voordat de onderzoeksresultaten zijn gepubliceerd, worden alle tot dan toe verzamelde gegevens definitief verwijderd. Echter, als de gegevens zijn geanonimiseerd

kunnen ze niet meer verwijderd worden omdat het dan niet meer mogelijk is de gegevens te herleiden naar individuele deelnemers.

Ongemak, risico's en verzekering

De risico's van deelname aan dit onderzoek zijn niet groter dan die in dagelijkse situaties thuis. Uit ervaring met voorgaande, vergelijkbare onderzoeken is gebleken dat er van enig ongemak voor de deelnemers niet of nauwelijks sprake is.

Bij elk onderzoek van de Universiteit van Amsterdam geldt een standaard aansprakelijkheidsverzekering.

Vertrouwelijkheid van uw persoonlijke gegevens

De gegevens die in dit onderzoek worden verzameld, zullen door de onderzoekers alleen worden gebruikt voor de doeleinden van dit project. In publicaties wordt geen gebruik gemaakt van uw persoonlijke gegevens, en u blijft onherleidbaar in alle publicaties.

De verzamelde onderzoeksgegevens zullen gecodeerd opgeslagen worden, apart van uw persoonlijke gegevens. Alleen medewerkers aan het onderzoek hebben toegang tot deze persoonsgegevens en de codering.

Geanonimiseerde gegevens zullen worden opgeslagen voor een periode van 10 jaar. De niet-geanonimiseerde gegevens zullen alleen worden opgeslagen zo lang het nodig is voor het onderzoek en zullen zo spoedig mogelijk worden verwijderd.

Rechten van betrokkenen onder de AVG

Deelnemers kunnen op elk ogenblik bij de onderzoeker om meer informatie vragen over hun rechten als betrokkenen onder EU privacy-wetgeving, de AVG.

Vergoeding

Er is geen vergoeding voor deelname aan dit onderzoek.

Nadere inlichtingen

Als u nog verdere informatie wilt over dit onderzoek, dan kunt u zich wenden tot dr. Roland Pfau (telefoon: +31 20 – 525 3022; e-mail: r.pfau@uva.nl; Spuistraat 134, 1012 VB Amsterdam, Nederland).

Met eventuele klachten over dit onderzoek kunt u zich wenden tot de secretaris van de Commissie Ethiek van de Faculteit Geesteswetenschappen van de Universiteit van Amsterdam; commissie-ethiek-fgw@uva.nl; Binnengasthuisstraat 9, 1012 ZA Amsterdam, Nederland.

Informed consent form (Dutch original)

'Ik verklaar hierbij op voor mij duidelijke wijze te zijn ingelicht over het onderzoek 'Het leren van gebaren en gebarencombinaties' van de Universiteit van Amsterdam, capaciteitsgroep

Taalwetenschap, uitgevoerd door Sigrid Bruinsma onder begeleiding van dr. Roland Pfau, zoals uiteengezet in de informatiebrochure. Mijn vragen zijn naar tevredenheid beantwoord.

Ik stem geheel vrijwillig in met deelname aan dit onderzoek. Ik behoud daarbij het recht deze instemming weer in te trekken zonder dat ik daarvoor een reden hoef op te geven. Ik besef dat ik op elk moment mag stoppen met het onderzoek en na het onderzoek mijn deelname altijd weer kan intrekken. In het geval dat ik mijn deelname staak of toestemming intrek zullen alle tot dan toe verzamelde gegevens definitief worden verwijderd.

Indien mijn onderzoeksresultaten gebruikt zullen worden in wetenschappelijke publicaties, dan wel op een andere manier openbaar worden gemaakt, zal dit volledig geanonimiseerd gebeuren. Mijn persoonsgegevens zullen niet door derden worden ingezien.

Als ik nog verdere informatie over het onderzoek zou willen krijgen, nu of in de toekomst, kan ik me wenden tot dr. Roland Pfau (telefoon: +31 20 – 525 3022; e-mail: r.pfau@uva.nl; Spuistraat 134, 1012 VB Amsterdam, Nederland).

Met eventuele klachten over dit onderzoek kan ik me wenden tot de secretaris van de Commissie Ethiek van de Faculteit Geesteswetenschappen van de Universiteit van Amsterdam; email: commissie-ethiek-fgw@uva.nl; Binnengasthuisstraat 9, 1012 ZA Amsterdam, Nederland.'

Ik geef toestemming om:

- deel te nemen aan dit onderzoek ☐ja / ☐nee

- mijn persoonsgegevens op te slaan voor een periode van 3 MAANDEN ☐ja / ☐nee

Information brochure (English translation)

Dear participant,

You will be taking part in the 'learning signs and sign combinations' research project conducted by Sigrid Bruinsma under supervision of Dr. Roland Pfau at the University of Amsterdam in the capacity group Linguistics. Before the research project can begin, it is important that you read about the procedures we will be applying. Make sure to read this brochure carefully.

Purpose of the research project

This research looks at how our thinking affects language. What is special about humans is that we can use language with words as well as signs. We want to know how people learn signs in a sign language they do not yet know. This research helps us know more about how people communicate.

Why is this research important?

• We learn how languages work

• It helps us understand why languages are different

Who can take part in this research?

Adult native speakers of Dutch between the ages of 16 and 60 are invited for this study. Given the nature of the study, it is important that you can see well. However, wearing glasses or contact lenses is possible. Furthermore, we will ask you some questions about your language background. You can participate in this examination if Dutch is your native language and you do not know any sign language. It is also important that, as far as you know, you do not have any memory or language problems, such as dyslexia or a specific language disorder.

Instructions and procedure

You first answer some general questions. Then you start learning. You see signs and follow a certain procedure to learn them. Then you do a task to see how your learning has proceeded. In this task, you match signed sentences to pictures. In total, the study takes 30 minutes.

Voluntary participation

You will be participating in this research project on a voluntary basis. This means you are free to stop taking part at any stage. This will not have any consequences and you will not be obliged to finish the procedures described above. You can always decide to withdraw your consent later on. If you decide to stop or withdraw your consent prior to publication of the research results, all the information gathered up until then will be permanently deleted. However, if information has been anonymised, it cannot be deleted because it is not possible to trace back the information to individual participants.

Discomfort, risks and insurance

The risks of participating in this research are no greater than in everyday situations at home. Previous experience in similar research has shown that no or hardly any discomfort is to be expected for participants.

For all research at the University of Amsterdam, a standard liability insurance applies.

Confidential treatment of your personal details

The information gathered over the course of this research will be used for the purpose of this research project. Your personal details will not be used in publications, and we guarantee that you will remain unidentifiable in all publications.

The data gathered during the research will only be accessible to the researcher and the supervisor of the researcher.

Anonymised data will be stored for a period of 10 years. After that, the data will be permanently deleted. The non-anonymised data will only be stored as long as is necessary for the research and will be deleted as soon as possible.

Data subject rights according to the GDPR
Participants can request more information from the researcher at any time about their rights as data subjects under the EU privacy law, the GDPR.

Reimbursement

Participants will not be reimbursed for their participation in this research.

Further information

For further information on the research project, please contact Dr. Roland Pfau (phone number: +31 20 525 3022; email: r.pfau@uva.nl; Spuistraat 134, 1012VB Amsterdam, The Netherlands).

If you have any complaints regarding this research project, you can contact the secretary of the Ethics Committee of the Faculty of Humanities of the University of Amsterdam, commissie-ethiek-fgw@uva.nl; Binnengasthuisstraat 9, 1012 ZA Amsterdam, The Netherlands

Informed consent form (English translation)

'I hereby declare that I have been clearly informed about the research project 'Learning signs and sign combinations' at the University of Amsterdam in the Faculty of Humanities conducted by Sigrid Bruinsma under supervision of Dr. Roland Pfau as described in the information brochure. My questions have been answered to my satisfaction.

I realise that participation in this research is on an entirely voluntary basis. I retain the right to revoke this consent without having to provide any reasons for my decision. I am aware that I am entitled to discontinue the research at any time, and that I can always withdraw my consent after the research has ended. If I decide to stop or withdraw my consent, all the information gathered up until then will be permanently deleted.

If my research results are used in scientific publications or made public in any other way, they will be fully anonymised. My personal information may not be viewed by third parties.

If I need any further information on the research, now or in the future, I can contact Dr. Roland Pfau (phone number: +31 20 525 3022; email: r.pfau@uva.nl; Spuistraat 134, 1012VB Amsterdam, The Netherlands).

If I have any complaints regarding this research, I can contact the secretary of the Ethics Committee of the Faculty of Humanities of the University of Amsterdam; email: commissie-ethiek-fgw@uva.nl; Binnengasthuisstraat 9, 1012 ZA Amsterdam, The Netherlands.

I consent to:

- participate in this research ☐yes / ☐no

- my personal details to be stored for a period of 3 MONTHS ☐yes / ☐no