Pronoun production and comprehension in American Sign Language: the interaction of space, grammar, and semantics

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ABSTRACT
Spoken language research has investigated how pronouns are influenced by grammar and semantics/pragmatics. In contrast, sign language research has focused on unambiguous pronominal reference arising from spatial co-reference. However, understanding signed pronouns contributes to cross-linguistically valid models of pronoun production and comprehension. In two sentence-continuation experiments, the present study investigated how linguistic use of space (modality-specific), antecedent grammatical role and verb implicit causality bias (modality-independent) affect American Sign Language (ASL) pronouns. Production of pronouns was determined by antecedent grammatical role, and overt pronouns were marginally more frequent for referents articulated in specific areas of signing space compared to neutral space. Signers interpreted pronouns using spatial information and, notably, verb bias, despite spatial co-reference supposedly removing the ambiguity that verb bias resolves. These findings demonstrate that ASL pronouns are subject to modality-independent factors, despite their use of space, and lend support to models of pronominal reference positing a production/comprehension asymmetry.

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1. Introduction
The production and comprehension of referential cohesion are complex processes that language users perform automatically and seemingly effortlessly. Uncovering the principles underlying these processes has played a central role in psycholinguistic research for the past decades, in particular with respect to pronominal reference. Sign language researchers, too, have a longstanding interest in pronouns. This is especially true for personal pronouns because of their modality-specific features. In many sign languages, overt pronouns are pointing signs that can be disambiguated via spatial co-reference, that is, through the space surrounding the signer, rather than through lexical features such as gender. Perhaps because of this, research on sign language pronouns has taken a somewhat different trajectory compared to work on spoken language pronouns. In particular, sign language linguistics has focused on discovering how spatial co-reference works in pronouns. Less attention has been paid to the possible effects of factors known to influence the processing of spoken language pronouns. Identifying the effect on these factors on signed pronouns, however, is of vital importance in order to discover a set of grammatical, semantic, and discourse-pragmatic factors that universally govern pronoun production and comprehension. The present paper reports on two experiments examining how factors specific to the visual-manual modality, such as spatial co-reference, and modality-independent factors, such as grammatical role and semantic verb biases, influence pronouns in American Sign Language (ASL). To preview, our findings reveal that although ASL pronouns show some effect of modality-specific factors as prior research has shown, this is the first study to demonstrate that ASL pronouns are strongly affected by factors that are present in spoken language as well. Moreover, the way in which the different factors affect pronouns in this particular sign language provides support for a model of pronominal reference predicting an asymmetry between production and comprehension.

2. Pronouns in American Sign Language
Like spoken languages, sign languages make use of a variety of referring expressions to create cohesion.
Among the more frequent referring expressions in American Sign Language (ASL) are nouns, overt pronouns, and null pronouns. While these expressions are also frequent in the spoken modality, the manual-visual modality shapes how these referring expressions are realised in sign languages (Friedman, 1975; Klima & Bellugi, 1979; Lillo-Martin, 1986). For example, when signers introduce (absent) entities into the discourse, they can do so with names or common nouns, just as in spoken languages. However, unlike the situation in spoken languages, signers have the option of spatially localising and thereby associating a nominal (and the denoted referent) with an area of signing space. The signing space is the space around the signer, primarily the front and sides and from the torso up (Figure 1).

Areas of signing space that are associated with nominals are called referential loci (Klima & Bellugi, 1979; Lillo-Martin & Klima, 1990). A referential locus can be created in different ways (Baker-Shenk & Cokely, 1980; Lillo-Martin, 1986; Padden, 1988), for example by articulating the nominal in the space that then becomes the locus. In Figure 2, for example, the signer first establishes “Scott” in the space to her left (“#SCOTT-L”, panel a) and “Tyra” in the space to her right (“#TYRA-R”, panel c) by fingerspelling the names to the left/right of her midline. It is also possible to precede or follow the noun with a pointing sign indexing a locus, or to accompany the nominal with an eye-gaze directed towards a locus. The established referential locus can subsequently contribute to cohesion in different ways. Third person singular anaphoric pronouns, for example, are pointing signs that can index areas of the signing space (Friedman, 1975). Such pronouns are often referred to as indexical pronouns, or IX for short. They can be understood by retrieving the referent associated with the indicated referential locus, as in Figure 2, where the signer refers back to “Tyra” by pointing to her right (“IX-R”, panel d). Thus, an ASL pronoun can refer unambiguously, and in fact, it is assumed that using spatial co-reference necessarily leads to a fully disambiguated pronoun. This contrasts with the situation in many spoken languages, where pronouns, despite matching lexical features of their referents, are referentially ambiguous in many contexts. As a result, some processes related to using and interpreting pronouns have been understood to be different in sign vs. speech.

2.1. Factors dependent and independent of modality in studies of signed pronouns

Much research has focused on the use of space in the resolution of signed pronouns. This is true in formal theoretical linguistics (Koulidobrova & Lillo-Martin, 2016; Kuhn, 2016; MacLaughlin, 1997; Neidle et al., 2000; Schlenker, 2011, 2013; Steinbach & Onea, 2016) and in experimental psycholinguistics (Emmorey, 1997; Emmorey & Lillo-Martin, 1995; Emmorey et al., 1991; Wienholz et al., 2018). The referential transparency of ASL pronouns suggests that they may be different from pronouns in spoken languages. Friedman (1975) explicitly argues for such a difference. For this reason, she does not consider pointing signs to be pronouns. While subsequent work has continued the debate about whether pointing signs should be considered partly or fully gestural (Cormier et al., 2013; Liddell, 2000, 2003) or linguistic (Lillo-Martin & Klima, 1990; Meier, 1990; Meier & Lillo-Martin, 2010; Perlmutter, 1991), the notion that the third person singular sign language pronoun has properties that are radically different from spoken language pronouns has largely persisted.

Given this literature, it is perhaps unsurprising that most studies have focused on what makes signed pronouns different from spoken ones. Only few experimental studies have included modality-independent factors in the production and resolution of pronouns in sign languages (see Emmorey, 1997; Emmorey & Lillo-Martin, 1995; Emmorey et al., 1991). It would be strange if the factors that have been documented to affect pronoun production and interpretation in many spoken languages (discussed below) played no role for sign language pronouns. Nevertheless, descriptions in previous sign language studies focus heavily on spatial factors. Sign language pronouns are generally explained by noting that, first the locus is established, and then the signer can direct pronouns towards it (see for example,
The focus on spatial factors likely results from the need to explain the linguistics of a unique phenomenon that only exists in sign languages. This has led studies of signed pronouns to rarely discuss ways for pronouns to be used and understood through non-spatial factors (explained in more detail below). The absence of ambiguity in localised signed pronouns offers a unique means to test the ubiquity of factors that have been argued to help disambiguate pronouns in spoken languages. Such study can inform models of referential coherence that are developed on the basis of spoken languages but are intended to capture universal linguistic and cognitive tendencies. A limited number of studies have discussed how signers interpret pronouns indexing areas of signing space that have not been explicitly pre-associated with referents. Engberg-Pedersen (1998) discusses an example of an undirected pointing sign, that is, not directed towards a locus. This sign can be resolved without problem because it occurs in an utterance that mentions only one referent. Studies by Ahn et al. (2019) and Koulidobrova and Lillo-Martin (2016) similarly find that IX to a neutral position (rather than to a referential locus) is interpretable when there is a unique, salient referent. Schlenker (2011) briefly mentions that signed pronouns can be subject to the first-mention effect (i.e. the first-mentioned NP in a sentence is the preferred referent for a pronoun). Finally, Wienholz et al. (2018) and Nuhbalaoglu (2018) discuss default associations in spatial co-reference. Wienholz et al. (2018) show that in the absence of overt associations between referents and loci, signers of German Sign Language (DGS) frequently associate sentential subjects with the right side of signing space, and sentential objects with the left side of signing space. Nuhbalaoglu (2018) shows that there may be language-specific preferences in how to use and interpret pronouns directed towards neutral positions. However, these studies have not investigated how the non-spatial influences that have been reported for spoken language pronoun resolution may also influence this process in sign language.

Similar to the situation for pronoun interpretation, very few studies have described how signers use pronouns that are not localised. Baker-Shenk and Cokely (1980) note that a pronoun may be used without prior establishment of a referential locus, if the referent is obvious, but offer no details regarding the factors that may make a referent obvious. Koulidobrova and Lillo-Martin (2016) also mention that the referent of a neutral IX should be easily recoverable. However, as neutral IX in their data were overwhelmingly deictic in usage, they do not analyse the conditions under which a pronoun referring to a non-present entity may be directed towards a neutral locus.

As we discuss below, there are several factors that influence how pronouns are produced and interpreted in spoken languages. Currently however, it is an empirical question whether these same factors are at work for sign language pronouns as well. It is unclear how unambiguous pronominal reference interacts with the factors that underlie spoken pronoun production and resolution. The question of whether using space to create unambiguous pronominal reference is preferred over other strategies for pronoun production and resolution in ASL not only addresses fundamental questions about ASL pronouns, but also serves as a test case for current theories of pronominal reference. The present paper reports on two experiments that investigate these issues.

3. Production and comprehension of pronouns

Pronouns are linguistically underspecified in most spoken languages. Therefore, their meaning must be interpreted within a given context. Consider the sentence fragment in 1). The first clause introduces the
referred referents “Lisa” and “Mary”, who are then both plausible referents for the pronoun in the second clause.

1) Lisa loves Mary, because she …

Given how unremarkable a sentence like 1) seems, it stands to reason that addressees do not find this type of (temporarily) ambiguous pronoun to be disruptive to the discourse. This has led to a large body of work attempting to identify the specific factors that guide the addressee in assigning a referent to a pronoun. A variety of heuristics have been proposed, including: a preference for a grammatical subject antecedent (Crawley et al., 1990; Frederiksen, 1982); a preference for assigning the pronoun to a referent with the same grammatical role (Chambers & Smyth, 1998; Grober et al., 1978; Smyth, 1994); a preference for the first-mentioned referent (Gernsbacher & Hargreaves, 1988; Gernsbacher et al., 1989); and a preference for assigning a pronoun to the thematic role favoured by a particular context (Stevenson et al., 1994). Other researchers have argued that the pronoun will be resolved to the most prominent referent, which in turn is determined by the interaction of several factors, such as subjecthood and semantics (Arnold, 2001), or that pronoun interpretation is guided by generalised reasoning and world knowledge (Hobbs, 1979).

As pointed out by Kehler and colleagues, an implicit assumption of the above accounts of pronouns is that the same principles apply to the production and resolution of pronouns (Kehler & Rohde, 2013, 2019; Kehler et al., 2008; Rohde & Kehler, 2014). The traditional assumption has been that producers signal referent accessibility with their choice of referring expression (Ariel, 1990; Chafe, 1976; Givón, 1983; Gundel et al., 1993). Consequently, producers should choose less semantically specific referring expressions, such as pronouns, exactly for referents that are highly activated in the comprehender’s mental discourse model. We will refer to this type of approach as the accessibility model. There is, however, evidence that the assumptions of the accessibility model do not hold and that, instead, the factors that guide pronoun production are partly dissociated from those that guide comprehension. In a study of pronouns in English, Stevenson et al. (1994) found that grammatical role appears to determine how a speaker will refer, such that pronouns are preferred for antecedents with the grammatical role of subject, and nominals are preferred for non-subject antecedents. This is referred to as the production bias. At the same time, Stevenson et al. found that semantically-based, top-down predictive processes are at play in determining which entity will be referenced, such that certain referents appear to be focused by the discourse context. These two principles work together. The preceding discourse context makes it more or less likely that a producer will re-mention a particular entity, but it is the grammatical role assigned to the entity in the preceding clause that determines whether or not the producer will use a pronoun for the re-mentioned entity. Crucially, this means that producers do not choose referring expressions as a function of referent accessibility. Instead, their rate of pronominalisation stays constant across the semantic/pragmatic contexts that foreground referents with different grammatical roles (Fukumura & van Gompel, 2010; Kehler et al., 2008; Miltsakaki, 2007).

To resolve a pronoun, comprehenders must essentially reverse engineer the referential intentions of the producer (Kehler & Rohde, 2019). The comprehender must draw inferences between sentences and use information from semantic/pragmatic sources to determine the likelihood that a given referent was mentioned. This information must then be combined with an estimate of the probability that the producer referred to the given entity with a pronoun. Specifically, encountering a pronoun increases the likelihood that a comprehender will interpret the sentence as being about a specific grammatical antecedent (i.e. the previous grammatical subject in English).

Kehler and Rohde (2013) proposed the Bayesian model of pronoun interpretation to capture these insights. The model is built on the idea of an asymmetry between pronoun production and interpretation: whereas pronoun interpretation is sensitive to the predictive processes that determine which referent will be re-mentioned (such as pragmatic biases), pronoun production is not. The choice of whether or not to pronominalise depends on information structure factors (such as the grammatical role of the antecedent). This stands in opposition to accessibility models (e.g. Ariel, 1990; Chafe, 1976; Givón, 1983; Gundel et al., 1993), which implicitly hold that pronoun production and comprehension are mirror images of each other. What little work that has examined the Bayesian model in languages other than English suggests that its principles largely apply cross-linguistically (Ueno & Kehler, 2016; Zhan et al., 2016; but see also Kaiser, 2013). It is unclear whether models that predict how speakers resolve ambiguity can account for the behaviour of sign language pronouns, given that their spatial nature has been postulated to make them unambiguous. As such, ASL pronouns provide a unique test case for the strength of different communicative resources that have been proposed to guide pronoun production and resolution.
3.1. Implicit causality and next-mention bias

The processes determining which referent is likely to be re-mentioned (which we will refer to as the next-mention bias following Rohde & Kehler, 2014) rely on different factors (Kehler, 2002; Kehler & Rohde, 2013, 2019; Kehler et al., 2008). Some of these factors are semantic, such as implicit causality.

Implicit causality (IC) verbs are interpersonal verbs (“surprise”, “love”, etc.), which implicitly assign causality to one of the verb’s arguments. This in turn results in a tendency to re-mention that referent in upcoming discourse (Au, 1986; Brown & Fish, 1983a, 1983b; Caramazza et al., 1977; Garvey & Caramazza, 1974, and others). Implicit causality verbs are generally grouped into two categories. One category is NP1, or subject-biased verbs. These are verbs, such as “annoy”, which elicit proportionally more re-mentions of the subject referent than of non-subject referents. The other category is NP2, or object-biased verbs, such as “love”, which elicit re-mentions of the object (or non-subject) referent. There is a corresponding bias towards resolving ambiguous pronouns to the causally implicated referent, that is, the subject referent in NP1-biased verbs and the object referent in NP2-biased verbs. Despite the next-mention bias, sentences where the referent is ultimately incongruent with the bias (e.g. “Lisa loves Mary, because she loves all her friends named Mary”) are not ungrammatical. However, parsing such sentences results in slower comprehension compared to congruent discourse (Caramazza et al., 1977; Ehrlich, 1980; Garnham & Oakhill, 1985; Koornneef & van Berkum, 2006; McKoon et al., 1993) as well as parsing difficulties, as evidenced by ERP research (Van Berkum et al., 2007).

Implicit causality verbs exist not only in English but also in many other languages (see Rudolph & Forsterling, 1997 and Hartshorne et al., 2013 for overviews of biases in multiple languages). Because implicit causality verbs exert a strong influence on which entity will be mentioned next, they shape the next-mention bias, influencing which referent producers will mention in upcoming discourse, and comprehenders use this information when resolving pronouns. Because of their demonstrated cross-linguistic importance, we would expect next-mention biases to affect pronouns in sign languages as well. To date, the effect of next-mention biases on pronouns has not been examined in a sign language. However, there are reasons to expect that such biases may play a different role in signed as opposed to spoken languages. When speakers interpret a pronoun, they do so in part by assessing the next-mention bias, that is, how likely it is that the producer re-mentioned a particular entity. This process helps to reduce the ambiguity of the pronoun. Yet, in the case of ASL, a pronoun can be unambiguous because of its use of space. This may remove the necessity of resolving ambiguity and reduce the reliance on next-mention biases for pronoun interpretation in ASL.

4. The present study

The ability to localise referents in space and the ensuing existence of a system of spatial co-reference has been the focus of investigations of ASL pronouns. This raises questions of whether factors known from spoken language research, such as grammatical role and the implicit causality bias of verbs, are relevant for ASL pronouns.

The focus on spatial localisation in sign language pronouns has primarily involved pronoun comprehension. It is possible that the production of ASL pronouns is affected by space as well, i.e. that the production of overt pronouns is licenced by referents having been previously localised in space. If so, it is an empirical question whether signers prefer other referring expressions over overt pronouns in the absence of spatial referent localisation. Moreover, whether or not overt pronouns are produced in both neutral and localised contexts, and how they are affected by factors such as verb bias and antecedent grammatical role offers a unique opportunity to examine the predictions of the accessibility model compared to the asymmetric Bayesian model.

When resolving pronouns, both models predict that pragmatic factors such as implicit causality biases are involved. In sign languages, however, spatial localisation might be a strong, possibly overriding, cue to interpreting the referent, because it is thought to make the referent unambiguous. This can be compared to gender marking in English when the two potential antecedents are differentiated by gender. In a sentence such as “Lisa annoys John because he …” we expect the pronoun to be resolved to “John” because of the gender marking, despite the fact that “Lisa” is the referent congruent with the NP1-biased verb. In the same way, we also expect the pronoun to be resolved to “John” in an ASL sentence such as “#LISA-R ANNOY #JOHN-L WHY? IX-L …”, because of spatial localisation. On the other hand, assuming that they do in fact occur in the absence of spatial localisation, overt pronouns in neutral contexts are ambiguous in the same way that same-gender pronouns are in English. It is an empirical question whether and how implicit causality biases are involved in interpreting overt pronouns both in the presence and absence of spatial localisation and consequently
whether models developed on the basis of spoken language can account for sign language pronouns.

To address these empirical questions, the present study examines the roles of spatial localisation, implicit causality verb bias, and the grammatical role of the antecedent in guiding the production and resolution of pronouns in American Sign Language (ASL). We designed two sentence-continuation experiments, one focused on pronoun production and one focused on pronoun interpretation. In both experiments, participants were presented with sentence-fragments naming two referents, one in subject position and one in object position. Subsequently, participants were asked to continue the sentences. We manipulated spatial localisation by varying where in relation to the signer the referent names were articulated. The names were fingerspelled using the manual alphabet, as in Figure 3. We created two localisation conditions in which referents were either associated with right/left referential loci (localised condition) or were not associated with such loci (neutral condition). In the neutral condition, both names were articulated in the area where fingerspelling generally occurs, that is, in roughly front of the shoulder of the signer’s dominant hand. In the localised condition, names were articulated to the right and left of the signer’s midline (Figure 4). We also manipulated next-mention biases using implicit causality (IC) verbs and unbiased (non-IC) verbs. As discussed above, IC verbs have been shown to predictably influence which referent will be mentioned next. NP1-biased verbs elicit continuations about the subject referent. NP2-biased verbs elicit continuations about the object (or non-subject) referent. Frederiksen and Mayberry (2021) found that IC biases occur in ASL, on par with what has been found for spoken languages (e.g. “SURPRISE” is an NP1-biased verb in ASL, similar to “surprise” in English) and gathered bias norming data for a large set of ASL verbs. We used these norms to select equal groups of NP1-biased, NP2-biased, and non-IC verbs.

4.1. Experiment 1

Here, we ask how the choice to pronominalise in ASL is influenced by modality-specific and modality-independent factors. If the choice of referring expressions in ASL is primarily a function of spatial localisation, then

Figure 3. The fingerspelled name #ADAM: #A (a), #D (b), #A (c), #M (d).

Figure 4. Left: Referent names fingerspelled in neutral space (neutral condition). Right: Referent names fingerspelled right/left of signer’s midline (localised condition).
using an overt pronoun is only, or primarily, felicitous in contexts where referential loci have been established. In the absence of spatial localisation, signers should instead rely on other referring expressions. Consequently, we would predict a higher rate of overt pronominalisation in the localised compared to the neutral condition. Discovering the conditions under which ASL signers use pronouns also offers the means to test the predictions of the two types of pronoun models. The accessibility model predicts that producers should choose less specific referring expressions for the referents that are assumed to be highly activated in the comprehender’s discourse model. The least semantically specified referring expressions in ASL are null pronouns and overt pronouns in the absence of spatial localisation (assuming that they in fact do occur with any regularity). Overt pronouns used in the context of spatial localisation are fully specified semantically, and are therefore predicted to be used for less accessible entities. Given the re-mention bias of IC verbs, the most accessible entities are those that the IC verb is biased to, that is, the previous subject following NP1-biased verbs and the previous object following NP2-biased verbs. Therefore, models focused on referent accessibility predict an interaction between localisation, verb bias and grammatical role of the antecedent. In contrast, the semantic specificity of the referring expression plays no role in the Bayesian model. This model instead predicts that only information structure factors play a role for production, specifically the grammatical role of the antecedent. As such, this model predicts similar rates of pronominalisation across localisation conditions, and no interaction between any of the factors of localisation, verb bias and grammatical role.

4.1.1. Methods

4.1.1.1. Participants. Sixteen Deaf, native ASL signers (12 female, mean age: 36 years, range: 23–59) participated in the experiment in return for monetary compensation. All had been exposed to ASL from birth by two Deaf parents, except for one participant who was exposed to another sign language (the participant did not disclose which one) and the sign system SEE (Signing Exact English) in the home and acquired ASL in high school. On a scale of 1–10, the participants’ average ASL self-ratings were 9.33 for production and 9.67 for comprehension. All signers were familiar with written English.

4.1.1.2. Materials. The stimulus items for this experiment consisted of 90 verbs occurring in NAME-1 VERB NAME-2 WHY? sentence-frames (e.g. “HOPE KICK CHAD WHY?”). The names were chosen from a list of 120 fingerspelled English 4-letter names (60 typically male and 60 typically female names). Each name occurred twice as the subject and twice as the object in the stimuli. The verbs were 30 NP1-biased (e.g. “FLATTER”), 30 NP2-biased (e.g. “ADMIRE”), and 30 non-IC verbs (e.g. “PASS”), taken from Frederiksen and Mayberry (2021). Frederiksen and Mayberry in turn based their verb selection on Ferstl et al. (2011). To avoid any effects of verb agreement, each group of verbs consisted of an equal number of agreeing and non-agreeing verbs. Each signer saw every verb once in the neutral condition, and once in the localised condition, for a total of 180 critical stimuli per signer. The experiment additionally contained 60 fillers, some of which were stimulus items for another experiment not reported here.

4.1.1.3. Procedure. Data were collected by video-recording the signers’ sentence continuations. Participants first gave consent and filled out a background questionnaire. They then watched a video recording with an explanation of the experiment in ASL and completed three practice trials. Following Frederiksen & Mayberry (2021), we used a sentence-continuation task based on previous spoken language research paradigms and adapted it to ASL (see for example Garvey & Cara-mazza, 1974; Stevenson et al., 1994). Signers were seated in front of a large computer screen displaying video recordings of a model signer (a Deaf, native ASL user) signing the experimental ASL stimuli. Participants first saw a prompt consisting of one sentence fragment stimulus. They then copied the prompt before adding their own continuation (Example 2).

2) Prompt signed by model: 

| Signers’ prompt copy and continuation: | “#AMIR-L CONTACT #JAKE-R WHYY?” “#AMIR-L CONTACT #JAKE-R WHY?” IX-L NEED HOMEWORK FROM IX-R” |

The repetition procedure was adapted to encourage signers to attend to and remember the prompt, and to replicate and internalise the spatial locations presented in the fragment. Participants were instructed to produce the first natural continuation that occurred to them. To ensure that they correctly understood the task, and particularly the repetition procedure, the participants were given three practice trials before the experiment, and the experimenter offered feedback where necessary, including asking the participant to repeat the prompt exactly. To avoid drawing attention to the fact that space was manipulated in the experiment, the feedback did not explicitly mention use of space. The experiment took 45–60 minutes.
4.1.2. Coding, evaluation and analysis
A Deaf, native ASL signer transcribed the participants’ video recorded responses. For each response to a critical trial, the coder noted the following: (1) the referent that was mentioned first in the continuation following the prompt repetition. We will refer to this as the next-mention; (2) the referring expression used for the next-mention; and (3) whether and how spatial localisation was applied in the copy of the prompt.

Next-mentions were coded as Subject, Object, Both, Other or Unclear, e.g. Subject in Example 2. Referring expressions were coded as Name (including name only, and any combination including a name (name + IX, name + possessive)), Pronoun (IX, IX + SELF,11 IX + classifier12), Null Pronoun, and Other (classifier, possessive, SELF), e.g. Pronoun in Example 2. Spatial localisation was coded as Manual, Non-manual or Absent. The participants manually indicated localisation in several ways: by fingerspelling names in different areas of space, by marking the location of referents through verb orientation or movement, or by adding pointing signs before or after names. Localisation could also be indicated non-manually with a head-tilt, body-lean, or eye gaze. In Example 2, the signer fingerspelled the names to the left and right of her midline. This was coded as manual spatial localisation through fingerspelling.

The responses from two randomly chosen subjects (12.5% of the dataset) were coded for reliability by a second coder who was also a Deaf, native ASL signer. The coders agreed on 92.9% of next-mentions (Cohen’s Kappa = .89), and on 98.1% of referring expressions (Cohen’s Kappa = .97). In cases of disagreement, the first coder’s judgment was retained. 12.8% of the data were excluded because no response was given, or the signer interpreted the verb differently than intended.

We focused on the responses where either the previous subject or object was chosen as the next-mention (n = 2510). The data were analysed using mixed-effect logistic regression (Jaeger, 2008). We fit models in R (R Core Team, 2014) using the lme4 package (Bates et al., 2014). Here and throughout the paper, we applied the following steps: we centred the three-level predictor, we estimate the main and interaction effects through likelihood-ratio tests comparing models that differ only in the fixed parameter in question. Throughout the paper, we report the mean proportions in the text and figures, where the error bars show +/-1 standard error.

4.1.3. Results
We first examined the overall distribution of referring expressions. Signers primarily produced overt pronouns for the next-mentions in their continuations (Overt Pronoun: 60%, Name: 24%, Null Pronoun: 15%, Other: 1%). We next asked whether the signers followed the prompt with respect to spatial localisation. An analysis of whether signers differentiated their use of manual localisation as a function of localisation in the prompt showed a significant effect of localisation condition ($\beta = 1.468, p < .001$). The signers used a higher mean rate of manual localisation in the localised condition (81%) compared to the neutral condition (68%). The mean proportion of responses marking location solely with non-manuals was higher in the neutral (12%) compared to the localised condition (8%). An analysis of the signers’ manual and non-manual localisation markers combined revealed a significant effect of localisation condition ($\beta = 1.349, p < .001$). Overall, signers localised referents at a mean rate of 89% in the localised condition vs. 81% in the neutral condition.

For the main analyses, we focused on referring expressions categorised as pronouns (null and overt) and names. We analysed both null and overt pronouns in order to obtain a fuller understanding of pronominalisation in ASL. We first compared overt pronouns to names, asking whether the rate of ASL overt pronouns vs. names varies with presence or absence of localisation in the sentence prompt, with verb bias and with grammatical role. If overt pronouns are licenced by the presence of spatial localisation, we expect to see a higher rate of overt pronominalisation in the localised condition. Further, if the predictions of the accessibility models hold, then we should see a higher rate of overt pronouns for the causally implicated referent in the neutral condition than in the localised condition, that is, we expect an interaction between localisation condition, verb bias, and grammatical role. If the predictions of the Bayesian model hold, we expect rates of pronominalisation to be similar across localisation conditions and instead to vary with grammatical role of the antecedent
only. Figure 5 shows overt pronounisation as a function of spatial localisation, verb bias and grammatical role of the antecedent, that is, whether next mention was of the previous subject or object. The analysis revealed a significant effect of grammatical role of the antecedent ($\beta = -1.175, p < .01$), with a higher mean proportion of overt pronouns (as compared to names) when re-mentioning the subject (80%) than when re-mentioning the object (70%). There was also a marginal effect of localisation condition ($\beta = 0.27, p = .053$), with a higher mean proportion of overt pronouns when referents were localised (74%) than when they were not (71%). Model comparisons showed no main effect ($p = .432, 2 \text{ d.f.}$) and no interaction effect of verb bias ($p = .239, 6 \text{ d.f.}$).

We next analysed whether the distribution of null pronouns compared to names is affected by localisation, verb bias and grammatical role (Figure 6). Here, the accessibility model predicts a higher rate of null pronouns for the causally implicated referent, whereas the Bayesian model predicts pronounisation to vary only as a function of the grammatical role of the antecedent. Null pronouns are not expected to vary as a function of spatial localisation. The analysis revealed a significant effect of grammatical role ($\beta = -2.652, p < .01$), with more null pronouns used for subject antecedents (71%) than object antecedents (34%). We found no effect of localisation ($\beta = -0.093, p = .73$). Model comparisons showed no difference between inclusion/exclusion of a verb bias interaction effect ($p = .13, 6 \text{ d.f.}$) but that including a main effect of verb bias is marginally better than excluding it ($p = .08, 2 \text{ d.f.}$).

Finally, we compared the distribution of null vs. overt pronouns to assess whether choice of pronoun differs as a function of spatial localisation, verb bias and antecedent grammatical role (Figure 7). The accessibility model predicts that null and neutral overt pronouns should be used for the causally implicated referent. The Bayesian model expects an effect of grammatical role only, but makes no predictions about different pronoun types preferring antecedents with different grammatical roles.

The analysis revealed an effect of grammatical role ($\beta = 1.614, p < .01$), with more overt pronouns for object antecedents (91%) than subject antecedents (68%), no effect of localisation ($\beta = 0.113, p = .494$), and model comparisons revealed no difference as a function of including/excluding verb bias main ($p = .104, 2 \text{ d.f.}$) and interaction effects ($p = .31, 6 \text{ d.f.}$).

4.1.4. Discussion

Overall, the results of Experiment 1 show that the choice to pronounise in ASL depends mainly on the modality-independent factor of the grammatical role of the antecedent, as predicted by the Bayesian

Figure 5. Proportion of overt pronoun vs. name references as a function of localisation condition, verb bias, and next mention.
pronoun model. Compared to names, both overt and null pronouns are preferred for next-mentions of the previous subject. However, compared to null pronouns, overt pronouns are used preferentially for object antecedents. This result is in line with previous research showing that null pronouns occur primarily with subject antecedents in ASL (Wulf et al., 2002). The other modality-independent factor, verb bias, was found to have limited influence on pronoun production, also as predicted by the Bayesian model. The interaction between verb bias and grammatical role predicted by the accessibility model was not found.

The modality-dependent factor, spatial localisation, affected choice of referring expression only in a limited
way. The presence or absence of spatial referential loci in the context sentence was not statistically significant and only marginal. Contrary to the prediction of the accessibility model, there were no interactions between spatial localisation, verb bias and grammatical role. Overall, this result is in line with the Bayesian model, which predicts no main effect of localisation. While there is a numerical difference in overt pronoun use in the two localisation conditions, overt pronouns are the preferred referring expression in both. As such, the absence of spatial localisation did not result in an avoidance of overt pronouns but only in a weaker pronoun preference. In addition to informing the larger debate about models of pronominal reference, the finding that overt pronouns occurred in both localisation conditions demonstrates that pre-established loci are not required for an overt pronoun to be licenced in ASL, similar to the findings of Ahn et al. (2019). This means that ASL overt pronouns are, at least in some contexts, semantically underspecified, as are spoken language overt pronouns. Signers can create discourse cohesion without using space.

Nevertheless, the numerical difference in overt pronoun use between conditions deserves some attention. Although past research in ASL has been interested in how overt pronouns are affected by localisation in space, the focus has been on pronoun interpretation. The present study is the first to extend the scope of this question to include the effects of space on pronoun production. Our finding that signers produce marginally more overt pronouns in localised contexts than in neutral contexts constitutes the first evidence that the rate of pronominalisation might be affected by the presence or absence of spatial referential loci. At this point, a picture emerges of ASL as using null pronouns for previous subjects and overt pronouns for previous objects and marginally more in the presence rather than the absence of referential loci. These findings indicate that, on the production side, ASL referring expressions are affected by both modality-specific and modality-independent factors in a way that largely supports the Bayesian model. We next examine whether the same set of factors governs how ASL signers resolve overt pronouns.

4.2. Experiment 2

Experiment 2 investigated the factors that guide resolution of ASL overt pronouns, and whether this varies as a function of whether referents in the input have been assigned referential loci or not. Pronoun resolution in English relies on the likelihood that a given referent was the next-mention, together with the probability that the referent was referred to with a pronoun, as shown by Kehler and colleagues (Kehler & Rohde, 2013; Kehler et al., 2008; Rohde & Kehler, 2014). If spatial localisation, when present, is the main driver of pronoun resolution in ASL, then we would expect pronouns in localised contexts to be interpreted in accordance with the referential locus they index. Correspondingly, we would also expect that a verb’s implicit causality bias should not play a role, because spatial co-reference is thought to lead to unambiguous pronominal reference. A key question is how pronouns are resolved in contexts where referents have not been associated with loci but are articulated in neutral space. We hypothesise that such pronouns will be resolved in accordance with the verb bias. Specifically, pronouns should be resolved to the causally implicated referent more frequently than to the non-causally implicated one. Thus, we expect pronouns in the localised condition to be interpreted in accordance with spatial co-reference, and we expect pronouns in the neutral condition, but not the localised one, to be interpreted in accordance with the verb bias.

4.2.1. Methods

4.2.1.1. Participants. Fifteen Deaf, native ASL signers (11 female, mean age: 30.4 years, range: 29–44) participated in the experiment in return for monetary compensation. None of these participants took part in Experiment 1. All had been exposed to ASL from birth by two Deaf parents, except for one participant whose parents were hearing and learned ASL and whose older sister was Deaf as well. The participants’ average ASL self-ratings were 9.73 for production and 9.93 for comprehension, on a scale from 1 to 10. All signers were familiar with written English. One additional signer was tested, but their data were excluded, as they did not follow the experiment instructions.

4.2.1.2. Materials and procedure. Experiment 2 used the same procedure and the same type of sentence continuation task as Experiment 1. As before, participants first saw a prompt consisting of one sentence fragment from the stimuli. They then copied the prompt before adding their own continuation. Before the experiment, participants completed three practice trials and were given feedback where necessary. The experiment took 30–50 minutes.

For this experiment, the sentence fragment included an overt pronoun, e.g. “NAME-1 VERB NAME-2 WHY? IX … ”. Keeping the referring expression in the continuation constant allowed us to focus on which referent the signer assigned to the pronoun. Thus, although signers were producing language in this task, our interest is in how they interpreted the provided pronoun.
For the critical stimuli, 72 different verbs were used in the sentence fragment. We used a subset of the verbs from Experiment 1; 24 verbs were NP1-biased, 24 were NP2-biased, and 24 were non-IC verbs. Each group of verbs consisted of an equal number of agreeing and non-agreeing verbs. We also included 24 filler items. Each stimulus item occurred once in the neutral condition, and once in the localised condition, for a total of 192 items (144 critical stimuli) per signer. The referent names were chosen from a list of 96 fingerspelled English 4-letter names (48 typically male and 48 typically female names). Each name occurred once as the subject and once as the object.

In the localised condition, we balanced trials in which reference to the subject or the object referent was articulated on the right/left of the signer. This was done in order to avoid any potential effect of signers associating the right/left side with subject or object by default. We also counterbalanced whether the pronoun indexed the referential locus associated with the previous subject or object.

4.2.2. Coding, evaluation and analysis

A Deaf, native ASL signer transcribed the video recorded responses and coded the next-mention in the signer’s continuation. The next-mention was generally the referent of the overt pronoun, but participants did not always follow the prompt in starting their continuation with an overt pronoun. In cases where they did not, the next-mention was whichever referent was mentioned as the subject of the continuation clause. Because not all continuations began with an overt pronoun, we additionally coded the referring expression used for the next-mention in order to understand the conditions under which this happened. Next-mention was determined based on spatial co-reference, if present, i.e. the pronoun was directed towards the space in which a name had previously been articulated (Example 3), and on the meaning of the entire utterance otherwise (Example 4). The coder also noted whether and how spatial localisation was used in the signer’s copy of the prompt. For purposes of reliability, a second Deaf, native ASL signer coded the data from three randomly chosen subjects (20% of the dataset). The two coders agreed on 92.9% of next-mentions (Cohen’s Kappa = .89), and on 98.1% of referring expressions (Cohen’s Kappa = .97). In cases of disagreement, the first coder’s judgment was retained.

3) #JACK-L RECOMMEND #ANNA-R WHY IX-R (=Anna) GOOD RESUME

4) #MAUD BAN #MIKE WHY IX (=Mike) #DIS-RESPECT-#FUL

Our analyses focused on responses in which the continuation began with an overt pronoun. Excluded were 39.6% of the total data which were primarily continuations starting with: Name = 15.6%, IX+ Name = 13.7%, and Ø = 8.6%. We also excluded 7.8% of the critical trials because no response was given or the signer interpreted the verb differently than intended (2.6%), because the next-mention was both of the referents (3.6%), because the next-mention was not one of the referents mentioned in the prompt (1.4%), or because the response was unclear (0.2%). We then modelled the remaining responses (n = 1135) with respect to how localisation and verb bias influenced interpretation of the pronoun as the entity previously introduced as subject or object. The model used localisation, verb bias, and the interaction between them as fixed-effect predictors.

4.2.3. Results

As in Experiment 1, we first asked whether signers followed the prompt with respect to presence or absence of spatial localisation. This analysis first examined whether the presence or absence of manual referent localisation was predicted by localisation condition (neutral vs. localised). The results showed a significant effect of manual localisation by condition (β = 1.651, p < .001), with less manual referent localisation in the neutral compared to the localised condition (57% vs. 82%). We also examined the sole use of non-manual markers to localise referents and found more non-manual localisation in the neutral compared to the localised condition (29% vs. 12%). We finally examined the rate of overall localisation by adding together manual and non-manual localisation. There was a significant effect of localisation condition on the mean proportion of localised responses (β = 1.07, p < .001), with more responses being either manually or non-manually localised in the localised compared to the neutral condition (86% vs. 93%).

Thus, although the signers localised more often than not in both conditions, there is a significant difference in rate of localisation between the two conditions, which is expected to affect pronoun interpretation. In addition, signers’ interpretation of the pronoun may be influenced by the presence or absence of localisation in the prompt, irrespective of how space was used in the signer’s production copying the prompt. We next assessed whether signers generally followed the prompt with respect to the intended referent of the pronoun in the localised trials. Pronouns in the prompts in the localised but not the neutral condition were designed to refer to either the previous subject or object, independent of the verb type. Examining the
localised trials revealed that signers did not always interpret the pronoun as intended (e.g. in some trials, the pronoun was interpreted as the object referent, despite being designed to refer to the subject referent). However, signers clearly attended to the meaning derived from referent localisation, as revealed by an analysis modelling next-mention with the indicated referent as a centred fixed-effect predictor. This analysis showed a significant effect of indicated referent ($\beta = 2.366, p < .001$), with a greater proportion of object mentions when the pronoun indicated the object compared to when it indicated the subject (78% vs. 41%).

Therefore, the evidence is overall in favour of signers generally following the prompt: the mean proportion of manual and overall localisation was significantly lower for the neutral compared to the localised condition. Further, in the localised condition the referent indicated in the prompt predicted the signers’ choice of next-mention. In other words, signers largely adopt the reference of the pronoun provided in the prompt. Thus, we include localisation as a predictor in the following analyses. The question of the greater proportion of non-manual localisation on trials in the neutral condition will be taken up in the general discussion.

For our main analysis, we first asked whether pronoun resolution (to the subject or object referent in the previous clause) varied as a function of localisation condition and verb bias. As discussed above, the prompts in the localised condition were designed to take advantage of spatial localisation in creating co-reference. By virtue of spatial localisation, the prompt pronoun referred unambiguously to the object in half the trials and to the subject in the other half. If localisation is the primary factor in pronoun resolution, we would expect similar rates of subject and object next-mention in this condition. The hypothesis here is that pronouns in the localised condition are resolved without reference to verb bias. In the neutral condition, by contrast, no spatial co-referential information was provided in the prompt. Consequently, we expected that signers would resort to resolving the pronoun in accordance with the next-mention bias, that is, to the subject in NP1-biased trials and the object in NP2-biased trials. This hypothesis predicts an interaction between localisation and verb bias.

Figure 8 shows how pronouns were resolved across verb types and spatial conditions. For clarity, the following figures show only object mentions. In the analysed data, pronoun resolution is always a binary choice between subject and object. Consequently, the proportion of subject mention is the inverse of the proportion of object mention.

Across verb types, the rate of object mention was 64% in the neutral and 59% in the localised condition with no main effect of localisation condition ($\beta = -0.369, p = .116$). Likelihood-ratio tests revealed verb bias as a significant predictor of next-mention ($p < .0001, 2 \text{ d.f.}$), and revealed no interaction with localisation condition ($p = .285, 2 \text{ d.f.}$). Signers showed a

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Figure 8. Proportion pronouns resolved to object by verb bias and localisation condition.
higher rate of object next-mention in the context of NP2-bias (86%) compared to non-IC (63%) and NP1-bias (36%), independent of localisation condition. Pairwise comparisons showed that these differences were significant between all verb types (NP1 vs. NP2, $\beta = -2.747$, $p < .001$; Non-IC vs. NP2, $\beta = -0.719$, $p < .05$; Non-IC vs. NP1, $\beta = 2.029$, $p < .001$). The absence of an effect of localisation condition could result from signers’ frequent use of localisation in the neutral condition. To rule out this possibility, we conducted an additional analysis of next-mention as a function of applied spatial localisation and verb bias. In this analysis, localised trials were those in which participants’ responses (rather than the prompt) contained localisation marking (either manual or non-manual). The results were similar to the original analysis. There was no effect of localisation ($\beta = 0.252$, $p = .35$). Model comparisons showed a main effect of verb bias ($p < .001$, 2 d.f.), and no interaction between verb bias and localisation ($p = .24$, 2 d.f.). Thus, next-mention (i.e. pronoun interpretation) was predicted by verb bias, but not by spatial localisation. Recall, however, that in the localised condition, half the prompts with an IC-biased verb contained a pronoun indexing the referent that was incongruent with the bias. In an NP2-biased context, the verb biases towards next-mention of the object. Consequently, a pronoun referring to the subject by virtue of spatial localisation creates an incongruency between verb bias and localisation. In an NP1-biased context an incongruency arises when a pronoun refers to the object by virtue of spatial localisation. Such congruency differences could obscure a sensitivity to spatial localisation. This is because signers might be less likely to interpret the pronoun as the referent indexed by the direction of the pronoun when this referent is not the one causally implicated by the verb. If so, then there should be a higher rate of object mentions in NP2-biased contexts compared to NP1-biased contexts. Likewise, we expect a higher rate of subject mentions in NP1-biased contexts compared to NP2-biased contexts. Such a pattern would suggest effects of both spatial localisation and verb bias. To assess whether this was the case, we examined how congruency influenced choice of next-mention for NP1 and NP2-biased verbs in localised trials. This analysis revealed that signers interpret the pronoun differently than indicated by the spatial coreference of the prompt exactly in the cases where the indicated referent was not the referent congruent with the verb bias. Specifically, the rate of object mention in NP1-biased trials was 14% when the prompt indicated the subject, and 65% when the pronoun indicated the object. In NP2-biased trials, the mean rate of object mention was 72% when the prompt indicated the subject and 99% when the pronoun indicated the object (Figure 9). We confirmed this by modelling next-mention with indicated referent (again centred), verb bias and their interaction as fixed effect predictors. Results showed a main effect of indication ($\beta = 2.715$, $p < .001$). Likelihood-ratio tests showed a main effect of verb bias ($p < .001$, 2 d.f.) and

![Figure 9. Proportion object mention in localised trials as a function of verb bias and indicated referent.](image-url)
no interaction between verb bias and indicated referent ($p = .193$, 2 d.f.).

Thus, we clearly see more mentions of subject or object when both verb bias and indication convene on the same referent. It is, however, noteworthy that this pattern is somewhat obscured because the bias towards the object is stronger in ASL comprehension than the bias towards the subject. Specifically, congruent trials led to more mentions of the causally implicated referent in NP2-biased contexts, i.e. object mentions, compared to in NP1-biased contexts, i.e. subject mentions (99% vs. 86%). This means that even when both spatial localisation and verb bias led to the subject as the referent of the pronoun, signers nevertheless resolved the pronoun to the object 14% of the time. Similarly, in NP2-biased contexts the difference in references to the causally implicated referent as a function of indicated referent was relatively small (99% when the indicated referent was the object vs. 72% when the indicated referent was the subject). The difference was larger in NP1-biased contexts (86% when the indicated referent was the subject vs. 35% when the indicated referent was the object). This indicates that seeing a pronoun indexing the object locus had a stronger effect than seeing one indexing the subject locus. This suggests an overall preference towards interpreting a pronoun as the object referent.

4.2.4. Discussion

Summarising the results of Experiment 2, our hypotheses of a main effect of localisation and an interaction between localisation and verb bias were not confirmed in the context of pronoun resolution in ASL. In both localisation conditions, the observed pattern replicates what has been reported for spoken language, namely that verb bias guides pronoun interpretation: the pronoun is more likely to be interpreted as the causally implicated referent than the non-implicated one. One might worry that the similarity of result in the localised condition compared to the neutral condition could be due to signers not actually using localisation as much as anticipated. However, considering how frequently signers localised referents in space across the experiment, but in particular in neutral prompts, the results suggest instead that the absence of a main effect of localisation arises in part from the two conditions sharing a high rather than a low rate of localisation. This is important because the contexts where spatial localisation is present are precisely those for which verb biases are predicted to be irrelevant.

Despite the apparent effect of verb bias, signers were also sensitive to the spatial co-reference information in the sentence fragment in localised trials. Their interpretation of the pronoun was influenced not only by verb bias, but also by the indicated referent in the prompt. Signers were the most likely to resolve the pronoun to the causally implicated referent when that referent was also the one indicated by the spatial setup in the prompt. Conversely, a conflict between the indicated referent and the causally implicated one elicited less reference to the causally implicated referent. As a result, we find similar rates of object mention when we compare next-mentions in incongruent trials, that is, how pronouns were resolved in NP1-biased contexts where the prompt indicated the object compared with NP2-biased contexts where the prompt indicated the subject.

Overall, these findings are remarkable. First, given the focus in the literature on the influence of referential loci, it is unexpected to find any influence of verb bias in ASL pronoun resolution. In addition, the results from the localised condition are noteworthy because they suggest that, although signers are sensitive to the co-reference pattern provided in the prompt, they frequently modify it in order to achieve congruency with the verb bias. This raises the question of what this modification consists of. One possibility is that signers disregard the spatial information in the pronoun in order to resolve the pronoun to the implicated referent in incongruent trials. Another possibility is that signers instead make modifications to the spatial setup of the prompt, essentially changing which referent is indicated by spatial co-reference. While a complete analysis of the strategies that participants employed to accomplish this is beyond the scope of the present paper, a limited examination of participants’ responses showed two different ways to achieve congruency between prompt and bias.

In the example shown in Figure 10, Participant 9 signed “#JILL VIDEO PHONE #JADE WHY? IX-R WANT MAKE PLAN FOR WEEKEND”, “Jill video-phoned Jade because she (Jill) wanted to make plans for the weekend”. Here, the participant localised the object, #JADE, to the left by using a subtle head-tilt towards the left (ht-L) at the end of the verb and the beginning of #JADE. Her continuation then started with a pronoun indexing her right side. In the prompt, #JILL was located left and #JADE right, and the pronoun was spatially co-referential with #JADE, the object antecedent. The verb, “VIDEO-CHAT-TO”, however, is NP1-biased. Thus, by localising #JADE left, the signer reversed the referential loci in the prompt, from #JILL-L and #JADE-R to #JILL-R and #JADE-L (Table 1). In this way, she achieved congruency between the pronoun (now indexing #JILL, the previous subject) and the NP1-biased verb “VIDEO-CHAT-TO”, at the cost of switching the referential loci compared to the sentence-fragment.
In an example with an NP2-biased verb, the same signer instead faithfully copied the referential loci from the prompt (“#SEAN-R R-KISS-L #HOPE-L WHY? IX-L …”) using verb agreement marking, but then changed which locus the pronoun was directed towards: “#SEAN R-KISS-L #HOPE WHY? IX-R LOVE IX-L”, “Sean kissed Hope because he loves her” (Table 1). Thus, signers clearly modify the spatial and co-referential setup of the prompt to avoid incongruence between pronoun and verb bias. Such changes do not generally appear to result from a disregard for spatial co-reference. Instead, signers modify sentences to accommodate both verb bias and spatial co-reference. This does, however, suggest that the exact spaces used for loci are more flexible compared to, for example, gender markers in spoken languages. Such flexibility is possible because unlike gender marking, spatial loci are not inherent features but instead depend on the discourse context.

### 4.3. Does seeing a pronoun bias signers towards object next-mention?

We finally asked whether the presence of a pronoun makes signers more likely to mention a given referent next, as has been found for speech (Rohde & Kehler, 2014; Stevenson et al., 1994). In English, a pronoun can increase the rate of subject mention with up to 35.2 percentage points (Rohde & Kehler, 2014). In the present study, we have seen more association of overt pronouns with object than subject antecedents: in Experiment 1, the comparison of null vs. overt pronouns showed more null pronouns for subjects and more overt pronouns for objects, and in Experiment 2, participants showed an overall preference for interpreting the pronoun as the object. We consequently expected that any effect resulting from seeing a pronoun would be towards more mentions of the object. We conducted a comparison between the overlapping verbs from Experiment 1 and Experiment 2. The data from Experiment 2 (1135 data points) all had pronoun prompts, and the data from Experiment 1 (1965 data points) all had free prompts.

**Figure 10.** Localising referents with head-tilt.

| Sentence Fragment | #JILL | VIDEO PHONE | #JADE | WHY? IX |
|-------------------|-------|-------------|-------|---------|
| Prompt L          | R     | R           | R     |         |
| Prompt copy       | R     | L           | R     |         |
| Sentence Fragment | #SEAN | KISS        | #HOPE | WHY? IX |
| Prompt R          | L     | L           |       |         |
| Prompt copy       | R     | L           | R     |         |

In an example with an NP2-biased verb, the same signer instead faithfully copied the referential loci from the prompt (“#SEAN-R R-KISS-L #HOPE-L WHY? IX-L …”) using verb agreement marking, but then changed which locus the pronoun was directed towards: “#SEAN R-KISS-L #HOPE WHY? IX-R LOVE IX-L”, “Sean kissed Hope because he loves her” (Table 1). Thus, signers clearly modify the spatial and co-referential setup of the prompt to avoid incongruence between pronoun and verb bias. Such changes do not generally appear to result from a disregard for spatial co-reference. Instead, signers modify sentences to accommodate both verb bias and spatial co-reference. This does, however, suggest that the exact spaces used for loci are more flexible compared to, for example, gender markers in spoken languages. Such flexibility is possible because unlike gender marking, spatial loci are not inherent features but instead depend on the discourse context.

**Table 1.** Spatial localisation in two prompts and in Participant 9’s prompt copies.

| Sentence Fragment | #JILL | VIDEO PHONE | #JADE | WHY? IX |
|-------------------|-------|-------------|-------|---------|
| Prompt L          | R     | R           | R     |         |
| Prompt copy       | R     | L           | R     |         |
| Sentence Fragment | #SEAN | KISS        | #HOPE | WHY? IX |
| Prompt R          | L     | L           |       |         |
| Prompt copy       | R     | L           | R     |         |
Prompt type was marginally significant in the model ($\beta = 0.426, p = .082$), with pronoun prompts being associated with higher rates of object next-mention than free prompts in all verb bias contexts in both the neutral condition (35% vs 28% for NP1-biased verbs, 89% vs. 83% for NP2-biased verbs, and 70% vs. 59% for non-IC verbs) and in the localised condition (37% vs. 24% for NP1-biased verbs, 84% vs. 83% for NP2-biased verbs, and 56% vs. 51% for non-IC verbs). This is despite the fact that the proportion of object reference in the localised condition in Experiment 2 is likely to be reduced compared to in spontaneous discourse, due to the effect of the indicated referent in the prompt. As per the experimental design, the indicated referent was the subject in half of the stimuli. Even though participants did not always adopt the referent indicated in the prompt as their next-mention, this design likely led to more subject next-mentions than would otherwise have occurred.

Thus, the comparison of rate of object next-mention as a function of prompt type suggests that ASL signers in fact prefer overt pronounisation of the object over the subject. While this grammatical role preference is by no means as clear as the subject preference in a language like English (e.g. Rohde & Kehler, 2014), it receives additional support from the results of Experiment 1 showing that in the comparison between null and overt pronouns the former are used more for subject antecedents than object antecedents and the latter are used more for object antecedents than subject antecedents.

5. General discussion

Unlike spoken language pronouns, ASL pronouns are thought to be unambiguous in the context of spatial co-reference. This raises the question of whether in the absence of referential ambiguity, ASL pronouns are nevertheless subject to the factors that guide pronoun production and interpretation in spoken languages. Here, we asked how the availability of space as a resource influences ASL pronouns and how this interacts with grammatical and semantic/pragmatic factors known to influence pronouns in spoken languages. Our results provide the first evidence that ASL pronouns are strongly influenced by factors that are not specific to the visual-manual modality but also reveal new insights about how space is used as a resource in the context of ASL pronouns.

In Experiment 1, we showed that the choice to pronounise depends to a large degree on the modality-independent factor of grammatical role of the antecedent, as predicted by the Bayesian model. While null pronouns preferred subject antecedents, overt pronouns were used more for objects compared to null pronouns, and more for subject antecedents compared to names. We found that overt pronouns were the preferred referring expression regardless of whether referents were localised in space or not, highlighting the fact that ASL overt pronouns can be used to create coherence even in the absence of referential loci. This suggests that they can be semantically
underspecified, the same as many spoken language pronouns. At the same time, we also showed for the first time that the rate of overt pronominalisation in ASL was affected by the presence or absence of spatial referential loci, with marginally more pronouns occurring in contexts of spatial localisation, compared to neutral contexts. This constitutes an important contribution of the present study because previous work has focused on assessing the effect of space on pronoun interpretation rather than production. In addition, although our findings show that localising referents is not necessary, signers appear to prefer it, frequently adding localisation where it was absent in the experimental stimuli.

In Experiment 2, we showed that ASL pronoun interpretation is only partially affected by the modality-specific effect of spatial co-reference. Pronoun interpretation did not vary as a function of the presence or absence of spatial referential loci in the prompt, suggesting that signers use similar processes to interpret pronoun regardless of whether referents have been localised in space or not. The primary predictor of whether an overt pronoun was interpreted as referring to the previous subject or object referent was the modality-independent influence of verb bias, and its effect was the same independent of whether referents were localised in space or not. We conclude that pragmatic factors guide interpretation of pronouns in spatially neutral contexts. Moreover, even in spatial contexts where pronouns are thought to be unambiguous, modality-independent factors exert strong influence on pronoun interpretation. Thus, it is clear that despite the unique properties of sign language pronouns, they remain subject to the same forces that guide pronoun production and interpretation in spoken languages. In addition, looking only at the trials where the referents were localised in space showed that signers were more likely to interpret pronouns in line with the verb bias when this interpretation was congruent with referent localisation, compared to when it was incongruent with referent localisation. Thus, while the effect of verb bias was strong, signers also used spatial co-reference information in their interpretation of the pronoun to some degree.

Experiment 2 also showed a limited effect on ASL pronoun interpretation of another modality-independent factor, namely grammatical role. Specifically, signers exhibited a numerical preference for interpreting pronouns as referring to previous objects. This was further supported by the fact that the forced pronoun continuations in Experiment 2 elicited marginally more continuations about the object than the subject compared to the free continuations in Experiment 1. Across Experiment 1 and 2, the findings of the present study show a division of labour between null and overt pronouns in ASL. Null pronouns prefer subject antecedents, and overt pronouns prefer object antecedents. In addition, overt pronouns were the preferred referring expression for both antecedents. It is possible, however, that overt pronoun for subjects is artificially stronger in the present study than in spontaneous conversational contexts. In our experimental design, pronouns in localised trial prompts were designed to refer to previous subjects and objects equally often. In the absence of experimental manipulation, ASL overt pronouns might show a stronger preference for object antecedents.

Overall, the results of the present study show that information structure factors (i.e. grammatical role of the antecedent) guides the choice to pronominalise in ASL, while semantic/pragmatic factors (i.e. verb bias) guides pronoun interpretation. This finding suggests that an asymmetry between production and comprehension applies across modalities, lending support to the Bayesian model.

5.1. Navigating spatial localisation and verb bias in ASL

The results of the present study also highlight that signers may prefer localised referents to neutral ones, even though localisation is not necessary for the creation of coherence. In the present study, signers regularly marked localisation, even when the prompt they were copying did not include it. This was true for the production and interpretation experiments, with signers applying (manual or non-manual) localisation to more than 60% of prompt copies in the neutral condition in Experiment 1, and to over 80% in Experiment 2. It is noteworthy that the lack of a main effect of localisation condition in Experiment 2 is due to the two conditions sharing a high rather than a low rate of localisation. This means that signers added spatial marking to responses in the neutral condition, and not, as one might have thought, that they failed to include spatial marking in responses in the localised condition. Also noteworthy is the finding that signers’ responses differed in the two conditions with respect to reliance on manual versus non-manual marking. Non-manual marking is subtle, and signers may be less conscious of it. If so, the greater proportion of non-manual marking in the neutral condition may suggest that signers were sensitive to the task instructions and followed them by limiting manual localisation when it was absent from the prompt. The subtlety of non-manual marking might have escaped conscious monitoring.
Although signers were sensitive to the spatial co-reference information supplied in the prompt, we also observed that they regularly changed the reference of the pronoun in order for their utterance to be congruent with the verb bias. They accomplished this by producing modifications to the prompt’s referential loci, or by changing which referential locus the pronoun indexed. Therefore, these modifications did not generally lead signers to disregard spatial co-reference. Signers were able to produce such modifications because they were asked to copy the prompt before providing their continuation. We adopted the prompt replication procedure for a variety of reasons including ensuring that signers were sufficiently familiar with the initial sentence fragment, and that their pronominal references were interpreted based on the spatial framework they adopted. At the same time that our procedure served this purpose, it also enabled signers to modify the spatial setup in the prompt, which limited control of localisation and of intended referent in the present study. While future studies will need to replicate this result without the prompt copy, it is nevertheless important to emphasise that signers’ modification of the prompt is in itself a significant source of evidence for the importance of verb biases for ASL pronouns. This is so because the modifications occurred mainly when the indicated referent was incongruent with the verb bias.

Findings from ERP and self-paced reading studies help contextualise the participants’ tendency to rearrange space to achieve congruency between pronoun and verb bias. As discussed in the introduction, previous work shows that listeners’ and readers’ processing is affected when the pronoun is incongruent with the verb bias. In addition, Rohde (2008) found that participants modified their production in order to avoid verb bias-pronoun incongruency. Rohde’s study manipulated congruency by using a male and a female referent and a gendered pronoun. Unlike the participants in the present study, her participants resolved incongruency by changing the coherence relation linking their sentence continuation to the context sentence. That is, when presented with an incongruent context sentence like “John infuriated Mary. She …” participants produced continuations focused on the result of Mary’s annoyance. In congruent contexts, the typical responses focused on the reason for John being infuriating. The present study held the coherence relation constant by using the connective “because”, and therefore, participants were unable to modify this to achieve bias-pronoun congruency. Instead, they resorted to changing, possibly subconsciously, the reference of the pronoun. The similarity between the results of these studies shows that English and ASL share a dispreference for verb bias-pronoun incongruence. The results also suggest that the two languages differ in how this type of incongruency can be resolved, although it remains an empirical question for future studies whether English speakers would also change the pronoun in contexts where the coherence relation is held constant.

Finally, most studies of pronouns and coherence relations have been conducted in the written version of a spoken language (with exceptions, such as Arnold, 2001, and particularly eyetracking and ERP studies, e.g. Arnold et al., 2000; Järvikivi et al., 2017; Van Berkum et al., 2007). Conducting experiments in writing is not an option for sign language research, so future research should aim to tease apart the extent to which variation in results across languages is a result of methodological differences in using writing vs. speaking/signing.

6. Conclusion

In two psycholinguistic experiments in American Sign Language, we examined for the first time how factors specific to the visual-manual modality and factors that exist irrespective of modality jointly influence the production and interpretation of overt pronouns in American Sign Language (ASL) and how this informs general models of pronoun production and interpretation. The particular modality-specific factor investigated here was the use of spatial referential loci. Sign languages are known to use space for reference. In the case of overt pronouns, the use of space can disambiguate possible pronoun antecedents. This has been assumed to make signed pronouns unambiguous, unlike spoken language pronouns, which are linguistically underspecified. To date, sign language research has not looked much beyond such effects to examine how factors that are not specific to the visual-manual modality might affect ASL pronouns. The present study tested the effects of two such factors, namely implicit causality biases and the grammatical role of the antecedent. Our results revealed that ASL pronouns are governed in large part by these modality-independent factors, specifically antecedent grammatical role in production and implicit causality biases in comprehension. These findings provide evidence that pronoun production and interpretation is similar not only across languages, but across modalities as well, and lend support to the framework of the Bayesian model of pronoun production and interpretation.

Notes

1. Speakers can also associate areas of space with referents through their co-speech gestures (see Foraker, 2011; Kendon & Versante, 2003; So et al., 2005, 2009).
2. Names and English words can be represented by spelling out the English letters with the manual alphabet in ASL. The manual alphabet consists of handshapes that correspond to letters in alphabet. Creating words by spelling them out with the manual alphabet is referred to as fingerspelling.

3. Some researchers have argued that pre-nominal and post-nominal points serve as definite and indefinite determiners, respectively in ASL (Neidle et al., 2000), but regardless whether these are or are not treated as determiners, they have the ability to anchor a nominal to a locus in the signing space.

4. Pointing signs are conventionally glossed as IX. We use a -R/-L tag to indicate where the pointing sign was directed (e.g. IX-R describes a pointing sign indexing a locus on the signer’s right side).

5. Although note that some studies have proposed that ASL overt pronouns are equivalent to spoken language demonstrative pronouns rather than personal pronouns (Koulidobrova & Lillo-Martin, 2016; McBurney, 2002, 2004).

6. In the remainder of this study, we focus on 3rd person singular pronouns.

7. Participants’ average written English self-ratings were 8.53 for production and 9.33 for comprehension. On a scale from 0 (=never) to 5 (=daily) participants rated their use of spoken English as 1.04 on average. Here and in Experiment 2, we report the participants’ knowledge of English to provide a measure of the degree to which participants are bilingual. Although not the focus of this paper, knowledge of a second language can affect language processing in the dominant language (Kroll et al., 2012).

8. The ASL conjunction ‘WHY’ is coordinating, rather than subordinating.

9. Agreeing verbs in sign languages use referential loci or hand orientation to indicate their subject and object arguments (in this paper, we include in the agreeing group verbs which only mark the object argument), and non-agreeing verbs do not (see Padden, 1988).

10. When facing the conversational partner, the addressee must mentally rotate the sender’s signing space in order to align referential loci with their own space (see discussion in Emmorey et al., 1993).

11. The sign glossed as SELF is an upright A-handshape. It has a variety of functions, including reflexive pronoun and nominalizer (Fischer & Johnson, 2012), and copular (Sampson & Mayberry, submitted).

12. Classifiers are handshapes or combinations of handshapes and tracing movements that represent salient visual features of referents (e.g. Supalla, 1982; Zwitserlood, 2012).

13. Non-convergence is a known problem of fitting models in R using lme4. We adopted the kind of pruning approach followed by Michael Frank and colleagues (see https://osf.io/zzqzu/wiki/Standard%20Analytic%20Procedures/).

14. The final model included only item random effects and by-subject random effects of localisation condition.

15. The final model included only item random effects and by-subject random effects of localisation condition.

16. The final model included only by-items and by-subjects random slopes for next mention.

17. The final model included only by-items and by-subjects random slopes for next mention.

18. Pairwise comparisons showed that this result was driven by a marginally significant difference between NP1-biased and NP2-biased verbs ($\beta = 0.933, p = .098$), with null pronouns occurring more frequently after NP1-biased than NP2-biased verbs (62% vs. 38%). There was no difference between NP1-biased verbs and non-IC verbs ($\beta = -0.293, p = .935$), nor between NP2-biased verbs and non-IC verbs ($\beta = 0.64, p = .724$).

19. The fact that the Bayesian model does not make predictions about the distinction between different types of pronouns is likely due to the fact that is has primarily been tested for English, which has only one type of pronoun.

20. The final model included only item random effects and by-subjects random slope for next-mention.

21. Although note that while Wulf et al. (2002) found null pronouns to be more frequent than overt pronouns in all grammatical contexts, the present results showed overall more references to previous subjects with overt than with null pronouns. Because other studies of ASL have found a prevalence of null reference in narratives (Frederiksen & Mayberry, 2016; Reynolds, 2018; Swabey, 2002, 2011), we attribute this difference to discourse genre, narrative vs. short unconnected discourses. Phenomena such as constructed action (e.g. Lillo-Martin, 2012) are less likely to occur in short discourses with multiple referents, because they afford limited opportunity to focus on one character. Null pronouns are highly frequent in constructed action contexts. This may account for the lower frequency of null pronouns in the short discourses of the present study compared to that of Wulf et al. (2002). Alternatively, Ahn et al. (2019) propose that the lack of contrasting referents in narratives may also result in fewer overt pronouns.

22. It is not entirely clear how to interpret the marginal main effect of verb bias on the rate of null pronominalisation, where contexts with NP1-biased verbs lead to more null pronouns than do NP2-biased verbs. The accessibility model does not predict this main effect. The Bayesian model predicts that there should be no interaction between verb bias and antecedent grammatical role, but does not necessarily make specific predictions about the main effect of verb bias. The strong interpretation of the model predicts that semantic and pragmatic factors should influence pronoun comprehension, but not production. The weak interpretation of the model only holds that pronoun interpretation should follow Bayesian principles and therefore does not make predictions about whether verb bias should influence production. Previous work has found mostly no effect of verb bias on pronoun production (Kehler & Rohde, 2013; Kehler et al., 2008; Rohde, 2008; Rohde & Kehler, 2014). However, like the present study, Zhan et al. (2016) found a main effect of verb bias on the production of pronouns. Neither the results of the present study nor those of Zhan et al. (2016) found that pronominalisation favoured the causally implicated referent, which would be expected if production mirrors comprehension. Thus, more work is needed to determine the significance of a main effect of verb bias on pronoun production.
23. Participants’ average written English self-ratings were 7.67 for production and 9.27 for comprehension. On a scale from 0 (=never) to 5 (=daily) participants on average rated their use of spoken English as 0.64.
24. The excluded responses were distributed as follows: 54% were trials in the neutral condition. Across localisation conditions there were more references to the object (58%) than to the subject (42%). The mean proportion of object references was 64% in neutral trials and 53% in localised trials, which is comparable to the distribution in the included data points.
25. The final included only item and subject random effects.
26. The final included only item and subject random effects.
27. The final model included only item effects and by-subjects random slope for indicated referent.
28. The final model included only item random effects and by-subjects random slope for localisation condition.
29. The final model included only item and subject random effects.
30. The final model included only item random effects and by-subject random slopes for indicated referent.
31. The final model included only item and subject random effects.

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