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# On the nature of role shift

## Insights from a comprehension study in different populations of LIS, LSC and LSF signers

**Valentina Aristodemo[1] · Beatrice Giustolisi[2] · Giorgia Zorzi[3] · Doriane Gras[1] · Charlotte Hauser[1] · Rita Sala[2,4] · Jordina Sánchez Amat[3] · Caterina Donati[1] · Carlo Cecchetto[2,4]**

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**Abstract**
Attitude role shift is a sign language strategy to report someone else's utterance or thought. It has been analyzed either as a kind of demonstration or, alternatively, as a complex construction involving subordination plus a context-shifting operator. The present work reports the results of a sentence-to-picture matching task developed in three different sign languages (Italian Sign Language, French Sign Language and Catalan Sign Language) with the aim of providing experimental evidence about the nature of role shift. The task assessed the comprehension of indexical first-person pronouns in various syntactic contexts with and without role shift. We showed that constructions with role shift, which require context-shifting for the first-person pronoun, are never easier to comprehend than constructions without role shift that do not require context-shifting. In some cases, they are even more difficult. Additionally, we show that, in Italian Sign Language only, sentences in which the role shifted first-person pronoun is in object position are more difficult than sentences in which it is in subject position. We argue that this can be interpreted as an intervention effect and that this is an argument in favor of positing a context-shifting operator in the periphery of the role shift clause. Considering that the population of adult Deaf signers includes, besides native signers, a majority of individuals with a more or less severe delayed first language exposure, the second goal of this paper is to study the effects of age of exposure on comprehension of sentences with role shift. In the three languages under investigation, we found that native signers generally outperformed non-native signers in sentences with role shift and in subordinate clauses without role shift. This confirms that delayed language exposure has a lasting impact on adults' comprehension of subordinate clauses of various degrees of complexity.

**Keywords** Role shift · Italian Sign Language · French Sign Language · Catalan Sign Language · Age of exposure · Age of acquisition · Direct quotation

V. Aristodemo and B. Giustolisi contributed equally to this work.

Extended author information available on the last page of the article

## 1 Introduction

One of the functions of language is that of reporting utterances produced by another individual. In spoken languages, this is accomplished in at least two ways: either directly, by assuming the perspective of the reported speaker, or indirectly, by referring to the target utterance from the perspective of the actual speaker (Banfield 1982; Coulmas 1986). In sign languages as well, signers can report utterances assuming, or not, the perspective of the reported signer. While indirect quotation is realized by embedding a subordinate clause under a verb of saying, as in spoken languages, the assumption of the perspective of the reported signer can be expressed through what is called role shift, a phenomenon whose syntactic nature is still under debate. Our first aim in this paper is to provide behavioral evidence that can contribute to this debate about the nature of role shift. The second goal of our work is to compare comprehension of role shift across three groups of Deaf[1] signers with different ages of first exposure to (sign) language (AoE). Moreover, the present study is part of a larger project which aims at developing clinical tests for language assessment. Therefore, we also have an applicative goal, i.e. to understand if the task that we developed concerning role shift can be a good candidate for a diagnostic tool in a clinical battery.

The paper is organized as follows: Sect. 2 focuses on role shift and presents the two main theoretical approaches that have been proposed to account for it; Sect. 3 offers a brief literature overview on the effects of AoE on language competence; Sect. 4 presents our study on the comprehension of role shift; Sect. 5 discusses our results; and finally Sect. 6 concludes the paper.

### 1.1 Notational conventions

Following standard conventions in sign language linguistics, glosses are given using small caps. Pronouns are indicated using the gloss IX followed by a subscript number for first, second or third person. We use square brackets with the subscript letters RS to indicate the part of the utterance under role shift. Subscript indices (e.g. $i$, $j$, $k$ ...) indicate the referent to which the indexical under role shift corresponds to. Finally, a line above the glosses signals the presence of non-manual marking and its scope.[2] The label above that line describes its grammatical function.

## 2 Main approaches to role shift

Role shift (see Lillo-Martin 2012 for an overview) is a common strategy[3] used in sign languages to report someone else's speech or thought (in so called attitude role shift)

[1] In this paper we use the word "Deaf" with capital "D" to refer to the deaf members of a community characterized by the use of a minority language (a sign language), with its own cultural identity. The word "deaf" with lower case "d" is instead used to refer to the audiological condition of being deaf.

[2] We did not conduct any systematic analysis of the role of non-manual markers (other than those involved in role shift) in our study. Therefore, we will not indicate them in the examples we discuss, unless they are cited from other studies.

[3] Cormier et al. (2015) show that role shift is widely attested in sign language corpora. Additionally, Cormier and Smith (2008) show that role shift is also the preferred strategy used by Deaf children in narratives.

**Fig. 1** Non-manual markers associated with role shift

or to describe physical actions performed by someone else (action role shift, also called constructed action). In both cases the signer assumes the perspective of ("becomes") the person whose thoughts, utterance or action is being reported. This change of perspective is signaled by a number of non-manual markers (NMMs), which can vary from sign language to sign language, but typically include: body shift towards the position associated with the individual whose perspective is adopted, eye gaze disconnection from the addressee, facial expressions altered in order to mimic those of the reported signer, and head turn, as exemplified in Fig. 1.

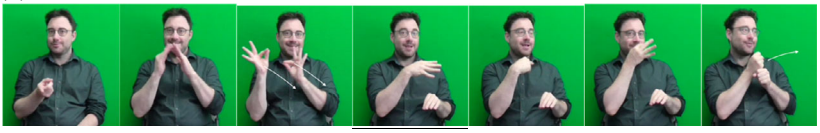
Attitude role shift, which is introduced by an attitude verb like SAY, is illustrated in (1), where the signer assumes the perspective of John.

(1) JOHN$_i$ SAY [$_{RS\text{-}i}$ IX$_1$ HAPPY]
'John says: I am happy.' (ASL, adapted from Davidson 2015)

Due to role shift, in (1) the reference of the indexical first-person pronoun is shifted from the actual context of utterance to the reported context, similarly to what happens in direct quotation in spoken English. As a result, in the sentence in (1) the indexical first-person pronoun IX$_1$ refers to John and not to the actual signer.

Action role shift is used to describe how an action is performed by the character whose perspective is adopted. For example, the role shifted sentence in (2) conveys the meaning that the person who did a donation of flowers is Gianni: the signer uses a first-person pronoun and the predicate DONATE is articulated with a trajectory starting from the signer's body and terminating into the locus in the signing space where Maria was previously established. Moreover, the NMMs indicate that the action of donating was done graciously, as the signer mimics the body language enacted by Gianni.

(2)



GIANNI$_i$ HOME ARRIVE. [$_{RS\text{-}i}$ MARIA IX$_1$ FLOWER $_1$DONATE$_2$]
'Gianni arrived. He donated flowers to Maria.' (LIS, adapted from Cecchetto 2020)

In this section we will briefly discuss the two main theoretical approaches to role shift.

The first claims that role shift should be analyzed as direct quotation (among others, Lee et al. 1997; Davidson 2015; Maier 2018). One of the most prominent works supporting this approach is Davidson (2015), in which the author proposes an analysis based on the notion of demonstration (Clark and Gerrig 1990). She claims that in role shifted sentences the verbs SAY or TELL introduce a demonstration that, even though unable to participate in cross-clausal syntactic and semantic processes (see below, examples (5)–(6)), is an argument of the matrix predicate, as also argued by Maier (2020). By using attitude role shift the signer does not just report what was said, but reports it *iconically*, namely in the way it was said. Similarly, by using action role shift the signer shows *how* an action was performed instead of simply saying that the action was performed. In this respect, although Davidson's account is a version of the direct quotation analysis based on colloquial expressions, she does not take as a model of direct quotation the one normally used in written spoken languages. Her idea is that attitude role shift might be the equivalent of English sentences introduced by "to be like," but for the fact that role shift, in contrast to English "like," is produced simultaneously with other lexical material, consistent with a tendency toward simultaneous verbal morphology in sign languages versus sequential morphology in spoken languages. We will call this type of approach to role shift 'demonstration analysis,' given the crucial role it attributes to demonstration.[4]

(3) He was like "This isn't fair" [said in a whiny voice].

In contrast with this view, others (Lillo-Martin 1995; Quer 2005; Schlenker 2017a, b) have proposed an account in which role shift involves embedding and the presence of a context-shifting operator. We will call this the 'context-shifting operator analysis.' To illustrate how this approach works, it is useful to start from Kaplan's (1989) classical analysis according to which indexicals are directly referential expressions. For example, the first-person pronoun *I* refers to the speaker of *some* context (where a context specifies at least agent, time, location, and possible world). The first-person pronoun *I* must refer to the speaker of the *actual* speech act in languages like English, and Kaplan hypothesized that this is language invariant. However, it is now well established that, in other languages, syntactic elements in the functional lexicon (operators) can change the context relative to which an indexical is interpreted (cf. Schlenker 2003; Zucchi 2004; Anand and Nevins 2004; Anand 2006; Herrmann and Steinbach 2012; Sudo 2012; Park 2016; Deal 2020; a.o.). In these languages, the first-person pronoun *I* can refer to the speaker of the *reported* speech act. For concreteness, take Schlenker's (2003) analysis of context shift in one of these languages, Amharic. He claims that attitude verbs quantify over contexts of speech and may bind free context variables. The first-person pronoun *I* in Amharic is lexically underspecified for its context variable, therefore it can be interpreted either as the speaker of the reported speech act or as the speaker of the actual speech act. On the contrary,

[4]Davidson (2015) applies her analysis in terms of demonstration to classifier predicate constructions as well. In the latter case, the demonstration is provided by the movement component associated to the handshape. In doing so, Davidson updates and revises Supalla's (1982) idea that action role shift is a subcategory of classifier constructions, in which the body of the signer represents an animate entity. In this paper we will not discuss classifier predicates any further.

the lexical specification of the English pronoun *I* is such that the context of interpretation must be the actual speech act. Going back to role shift, under this perspective, sentences with role shift require an operation of context shift that is not required in sentences without role shift and this is achieved by a context shifting operator. As for the structural position of this context-shifting operator, also referred to as role shift operator, the natural hypothesis is that it is hosted in a dedicated position in the CP area of the role shift clause. Therefore, the lexical material uttered under role shift would be the signs contained in the c-command domain of the role shift operator.

Partial shift refers to the fact that some indexicals do not obligatorily shift and by default are evaluated with respect to the context of the speech act, while some other indexicals in the same role shift clause are evaluated with respect to the shifted context. Partial shifting has been identified in Catalan Sign Language (LSC) by Quer (2005), but its presence has been described in DGS (German Sign Language) as well (Herrmann and Steinbach 2012). For example, in (4), the first-person pronoun $\text{IX}_1$ is interpreted with respect to the shifted context (i.e. it refers to Joan), while the deictic HERE does not refer to the location of the shifted context (i.e. Madrid), but rather to the location of the actual speech act (i.e. Barcelona).

(4) Uttered in Barcelona:

*topic*

$\text{IX}_3$ $\text{MADRID}_a$ MOMENT $\text{JOAN}_i$ $[_{\text{RS-}i}$ THINK $\text{IX}_1$ STUDY FINISH $\text{HERE}_b]$

'When he was in Madrid, Joan thought he would finish his study here (in Barcelona).' (LSC, adapted from Quer 2005)

More generally, Quer shows that personal indexicals under role shift are obligatorily shifted to the reported context, while others (e.g. temporal and local indexicals) can be optionally evaluated with respect to either the actual context or the shifted context.[5] As this phenomenon is not allowed in standard direct quotation in spoken languages, where all indexicals must shift their reference from the actual to the shifted context, this type of evidence has been interpreted by Quer as an argument against approaches like the demonstration analysis that stress the analogy with direct quotation.

However, data concerning partial role shift are by no means a knock-down argument against the demonstration analysis. For one thing, Nikitina (2012) reports similar phenomena in spoken languages. Second, Maier (2018) proposed an analysis of partial role shift based on Davidson's approach and on a pragmatic principle called *Attraction*. This principle states: "When talking about the most salient speech act participants in your immediate surroundings, use indexicals to refer to them directly." The principle rests on the specification of what "referring directly" and "speech act participants in your immediate surroundings" mean. As for "referring directly," the idea is that in sign languages this involves the use of a pointing sign. As for "speech act participants in your immediate surroundings," these include the signer, the addressee, the time and the location of the utterance. To exemplify, in order to refer to Barcelona, I will use HERE rather than the proper name 'Barcelona,' if I am located

[5] Sign languages behave differently with respect to this linguistic property. While partial shift is attested in LSC and DGS (Quer 2005; Herrmann and Steinbach 2012), it is not the case for other sign languages such as LSF and ASL (Schlenker 2017a, 2017b). It is worth noting that presence/absence of partial shift in LIS has not been investigated yet.

in that city. Therefore, in example (4), following the Attraction principle, Barcelona should be referred to by using the indexical HERE. However, in (4), the signer is also using role shift, which normally triggers indexical shift from the context of speech to the reported context, i.e. from Barcelona to Madrid. Therefore, the signer should not use HERE to refer to Barcelona. Maier proposes that this tension is resolved by unquoting the indexical element HERE under role shift, which therefore can refer to Barcelona and thus comply with the Attraction principle.[6]

It seems fair to conclude that the two opposing approaches can both accommodate the data on partial shift, although in different ways. Under the demonstration analysis it must be assumed that the demonstration relation does not necessarily apply holistically to the entire role-shifted sentence, but can apply only to some sub-parts. Under the context shift operator analysis, it must be assumed the operator selectively binds some variables but not others (or, as in Deal's 2020 analysis, partial shifting may arise because there are different operators in the left periphery of the embedded clause, each targeting a specific context parameter).

A second piece of evidence that might in principle adjudicate between the two competing approaches to role shift is (*wh*-) extraction from the role shifted clause. Lillo-Martin (1995) and Schlenker (2017a) both claim that extraction from a role shifted clause is possible in ASL; see (5).

(5) *Context*: The speaker is in NYC; the listener was recently in LA with John.
BEFORE $IX_3$ $JOHN_i$ IN LA, WHO $IX_3$SAY [$_{RS\text{-}i}$ $IX_1$ WILL LIVE WITH ___ HERE] WHO
'While John was in LA, who did he say he would live with there?'
(ASL, adapted from Schlenker 2017a)

This behavior is in contrast with what is observed in standard direct quotation in English, where *wh*-extraction of an argument out of the reported clause is not allowed, as shown in (6).

(6) a. John said: "I understand this"
b. *What$_i$ did John say: "I understand ___$_i$"?

This restriction holds also for the oral-style 'be like' quotation discussed by Davidson. Based on this evidence, researchers like Zucchi (2004); Quer (2005); Herrmann and Steinbach (2012); and Schlenker (2017a) defend the context-shifting operator analysis, because only under this analysis is the role shift clause an ordinary complement clause and as such, transparent to *wh*-extraction.

The problem with this argument might be empirical. As recognized by Schlenker (2017a), eliciting acceptability judgments is particularly complex in this area and the data are not completely clear-cut. For example, extractability seems to be possible in some languages (ASL) and not in others (LSF).

In conclusion, the choice concerning the right analysis to be given to role shift is still open. Given this situation, it is our goal to contribute to this debate by pro-

[6]Hübl et al. (2019) make an interesting attempt to test the quotation plus Attraction Principle analysis by using a controlled data elicitation task in German Sign Language (DGS). However, as they point out, given the small number of participants (only five), no statistical analysis of the results was possible and results are rather inconclusive.

viding experimental evidence on the comprehension of sentences containing attitude role shift as compared to the comprehension of sentences containing indirect quotation. Specifically, we will use a particular angle. Our logic is the following: if context shift is due to an operator and this is represented in syntax, in principle this operator might be sensitive to structural constraints that other syntactic operators are sensitive to. For example, as is well-known, in questions and relative clauses, the properties of the *wh*-operator are such that object dependencies are harder than subject dependencies. By the same logic, assume that a context shift operator sits in Spec,CP and consider a sentence in which the to-be-shifted variable is in object position ('object dependency') and a minimally different sentence in which the to-be-shifted variable is in subject position ('subject dependency'). If no difference arises between subject and object dependency, no clear conclusion can be drawn, as this null result may be due to different reasons. But if object context shift dependencies are indeed harder, this might be given a natural explanation under the context shift operator analysis (assuming that the context-shifting operator is syntactically represented), while the same pattern is more difficult to explain under the demonstration analysis.

As our experiments all focus on attitude role shift, from now on we will use the acronym RS, with the proviso that, unless the contrary is explicitly stated, RS means *attitude* role shift.

## 3 Effects of age of first exposure on language competence

Early exposure to language, no matter what modality, is crucial to language acquisition (Mayberry et al. 2002). If being exposed to one language (or more) from birth is the rule for hearing babies, this is not the case for deaf babies. As is well known, less than 10% of deaf children are born in Deaf families (Mitchell and Karchmer 2004), receiving this linguistic input from birth. The vast majority of deaf babies are born in hearing families and are thus exposed to a language that is not immediately accessible to them. This means that language exposure for these children is delayed, a delay that depends on the age of diagnosis (which has dramatically decreased recently due to newborn hearing screening; Joint Committee on Infant Hearing 2019) and on the type of language intervention that the parents decide to adopt (exposure to spoken language via amplification through hearing aids or cochlear implants, exposure to both spoken and sign languages, or exposure to sign language only). Only a minority of deaf children born in hearing families is exposed to sign language shortly after diagnosis. Others encounter sign language later in life, usually (but not always) as a consequence of a failure in spoken language learning. This means that the population of deaf pre-lingual adult signers is a heterogeneous mix of native and non-native signers, including individuals with a severely delayed exposure to language *tout court*.

Several studies investigated the impact of delayed (fully accessible) language exposure on sign language competence, reporting significant effects of age of exposure (AoE, also referred to as age of first language acquisition, AoA). We briefly report here the most significant findings focusing on behavioral studies (to deepen the topic, see the literature reported in Mayberry and Kluender 2018, paragraph 3).[7]

[7]Effects of AoE have also been reported in neurolinguistic data, which all together highlight that late exposure to language affects the brain functionally, structurally, and electrophysiologically (see e.g. Neville

The first works on the topic date back to the late 1980s/early 1990s. Non-native L1 signers were found to differ from native signers in the morphological generalizations adopted during the acquisition of verbs in ASL (Newport 1988), and only native signers, but not late signers (mean AoE = 12 years), were sensitive to agreement errors (Emmorey et al. 1995). When asked to immediately recall a sequence of complex ASL sentences, or to shadow ASL narratives, the performance of L1 signers decreased as AoE increased (Mayberry and Fischer 1989; Mayberry 1993). Moreover, Mayberry (1993) found that the performance of non-native L1 signers was worse than that of non-native L2 signers who acquired ASL at the same age. The group of L2 signers was composed of children who had become deaf after they had acquired English (post-lingual deafness). This showed that early/native exposure to language has an impact on the subsequent learning of another language, even if the two languages differ in modality. Effects of AoE have also been reported for early phonological processes and lexical access. Non-native signers recognized lexical signs slower in a psycholinguistic task employing a gating technique (Emmorey and Corina 1990).

Subsequent works confirmed and expanded the early findings. Using a timed grammatical judgment task, Boudreault and Mayberry (2006) found that the performance of non-native ASL signers decreased as AoE increased, regardless of the syntactic structure investigated. The authors tested early-acquired syntactic structures like simple sentences, negation, verbal agreement, and late-acquired syntactic structures, like *wh*-questions, relative clauses and classifier sentences. Using a British Sign Language (BSL) version of Boudreault and Mayberry's task, Cormier et al. (2012) found that accuracy in the grammatical judgment task decreased as AoE increased for Deaf signers exposed to BSL between 2 and 8 years of age (defined as early signers in the study). AoE had no effect on Deaf signers exposed to BSL between 9 and 18 years of age (defined as late signers in the study). Considering that English reading performance was higher for late signers compared to early signers, the authors suggested that their group of late signers was probably composed of people who had English as L1, and who acquired BSL as an L2.

As briefly reviewed, the vast majority of studies on AoE effects comes from ASL. With this paper we extend the existing findings by focusing on three different sign languages understudied from this perspective: Italian Sign Language (LIS), French Sign Language (LSF) and Catalan Sign Language (LSC) (see Hauser et al. 2021, Cecchetto et al. 2021 and Zorzi et al. to appear for other recent works from our research group focusing on these sign languages). Even if the studies on AoE dealt with various linguistic structures, as far as we know, to date no study on AoE effects focuses on RS. Our goal is thus also to fill this gap by specifically investigating sentences with RS compared to similar sentences without RS.

et al. 1997 for an ERP study with ASL signers; MacSweeney et al. 2008 for an fMRI study with BSL signers; Pénicaud et al. 2013 for an anatomical MRI study with ASL signers; Cheng et al. 2019 for a DTI study with ASL signers; and Malaia et al. 2020 for an ERP study with Austrian Sign Language signers).

## 4 The present study

This section presents our experiments on RS.[8] We developed a sentence-to-picture matching task with three goals. Our first aim was to contribute to the theoretical debate about RS by testing the predictions of the analysis positing a context-shifting operator. The second was to study the possible effects of AoE on this modality-specific construction and the third was to understand if the task we designed could be a good candidate for a clinical test. We considered three different groups of signers: native signers (exposed to the target sign language from birth and with at least one deaf parent), early signers (exposed to their sign language before the age of 6), and late signers (exposed between the age of 6 and the age of 15).

We had the following hypotheses:

(7) I. If RS involves a complement clause hosting a context-shifting operator sitting in the CP area and if the context-shifting operator obeys the same syntactic constraints as *wh*-operators, RS sentences should display effects of locality that are comparable to the ones reported for relative clauses and *wh*-questions.

II. In general, native signers should outperform early and late signers and we expect this effect to be modulated by the presence of RS.

Given our aims and hypotheses, our experiments included sentences with RS and without RS. We included sentences in which the first-person pronoun to be shifted was in subject position and sentences in which the first-person pronoun to be shifted was in object position, to study differences (if any) between subject and object RS dependencies. As explained in Sect. 2, this might offer evidence to decide between the demonstration analysis and the context shifting operator analysis. A third type of sentence was included in which the first-person pronoun to be shifted was a possessive. These sentences are expected to be simpler since they correspond to small clauses, functionally equivalent to a copular sentence. This last type of sentence was added considering our practical purpose of eventually developing a clinical test, which should include items easy enough to be administered to a clinical population.

### 4.1 Methods

#### 4.1.1 Participants

Participants were selected following three general inclusion criteria: i) onset of deafness no later than three years of age; ii) first exposure to sign language no later than 15 years of age; iii) the target sign language as their preferred means of communication.

[8] Raw video materials and data are available on an OSF repository (https://osf.io/emp6g/). The code to perform the analysis is also available from the repository. The RS comprehension tests presented in this paper are part of the SIGN-HUB assessment tests (https://www.sign-hub.eu/assessment/welcome-page-assessment) and are named respectively SYNTRSLSF - Role shift comprehension task in LSF (Aristodemo et al. 2019), SYNTRSLIS - Role shift comprehension task in LIS (Sala et al. 2019), SYNTRSLSC - Role shift comprehension task in LSC (Zorzi et al. 2019a).

**Fig. 2** Example of one item of the Odd One Out Cognitive Task

All participants declared not to have cognitive disabilities. Moreover, they were tested with an Odd One Out Cognitive Task, which was designed to signal potential cases of cognitive decline.[9] In this test, participants needed to find the intruder in a set of four pictures (see Fig. 2 for an example). The Odd One Out Cognitive Task consisted of 28 items preceded by two training items. For each participant, considering language group mean and standard deviations, z-scores were calculated. Participants with z-scores lower than −2.5 were excluded from the study.

In each language, we divided the participants into three groups: native signers, early signers and late signers. Native signers were exposed to sign language from birth (AoE = 0) and had at least one signing parent or signing close relative. Early signers were exposed to sign language before entering primary school (AoE range: 2–5) and late signers were exposed to sign language during compulsory school (AoE range: 6–15).

**4.1.1.1 LIS** Forty-three Italian Deaf LIS signers were selected (20 women, 23 men) based on our inclusion criteria, and one participant with a z-score of −3.94 in the Odd One Out test was excluded. The remaining 42 participants were divided into the three groups as summarized in Table 1. Some details about specific characteristics of the participants are given in Appendix 1.

Three Kruskall-Wallis tests showed that: i) the age difference between the groups was not statistically significant ($H(2) = 4.714$, $p = .10$); ii) the difference between the groups' mean z-scores in the Odd One Out test was not significant ($H(2) = 1.845$, $p = .40$); iii) the three groups did not significantly differ for level of education ($H(2) = 2.104$, $p = .35$).

**4.1.1.2 LSF** Forty-three French Deaf LSF signers were selected (23 women, 20 men), divided in groups as reported in Table 2. Individual characteristics of the participants are given in Appendix 2.

One ANOVA and two Kruskall-Wallis tests showed that the three groups did not differ for: i) age ($F(2) = 1.541$, $p = .23$); ii) z-scores in the Odd One Out test ($H(2) = 1.595$, $p = .45$); iii) level of education ($H(2) = 0.816$, $p = .67$).

**4.1.1.3 LSC** Forty Catalan Deaf LSC signers were selected (20 women and 20 men). One participant, with a z-score in the cognitive Odd One Out test of −5.51, was excluded from the analysis. The remaining 39 participants were divided as summarized in Table 3. Individual characteristics of the participants are given in Appendix 3.

[9]The test was the same, with instructions translated either in LSF, LIS or LSC. They are stored in the SIG-HUB platform under the following labels: COGONEOUTLSF (Aristodemo and Friedmann 2019) for LSF; COGONEOUTLIS (Giustolisi and Friedmann 2019) for LIS; COGONEOUTLSC (Zorzi et al. 2019b) for LSC.

**Table 1** Summary of the biographical characteristics of the three groups of LIS signers and summary of the Odd One Out test (cognitive z-score)

| GROUP | N | AGE | AoE | COGNITIVE Z-SCORE | LEVEL OF EDUCATION |
|---|---|---|---|---|---|
| NATIVE | 15 | M = 43 y<br>SD = 6 y | | M = 0.16 SD = 0.90 | Median = high school |
| EARLY | 15 | M = 47 y<br>SD = 9 y | M = 4 y<br>SD = 1 y | M = −0.21 SD = 0.97 | Median = high school |
| LATE | 12 | M = 50 y<br>SD = 9 y | M = 9 y<br>SD = 3 y | M = 0.00 SD = 0.51 | Median = high school |

**Table 2** Summary of the biographical characteristics of the three groups of LSF signers and summary of the Odd One Out test (cognitive z-score)

| GROUP | N | AGE | AoE | COGNITIVE Z-SCORE | LEVEL OF EDUCATION |
|---|---|---|---|---|---|
| NATIVE | 14 | M = 39 y<br>SD = 10 y | | M = −0.21 SD = 0.91 | Median = university education |
| EARLY | 15 | M = 34 y<br>SD = 7 y | M = 3 y<br>SD = 1 y | M = 0.19 SD = 1.09 | Median = university education |
| LATE | 14 | M = 40 y<br>SD = 13 y | M = 9 y<br>SD = 3 y | M = −0.08 SD = 1.00 | Median = high school |

**Table 3** Summary of the biographical characteristics of the three groups of LSC signers and summary of the Odd One Out test (cognitive z-score)

| GROUP | N | AGE | AoE | COGNITIVE Z-SCORE | LEVEL OF EDUCATION |
|---|---|---|---|---|---|
| NATIVE | 13 | M = 42 y<br>SD = 13 y | | M = 0.03 SD = 0.54 | Median = middle school |
| EARLY | 15 | M = 51 y<br>SD = 11 y | M = 3 y<br>SD = 1 y | M = 0.22 SD = 0.31 | Median = middle school |
| LATE | 11 | M = 53y<br>SD = 8 y | M = 10 y<br>SD = 3 y | M = 0.25 SD = 0.40 | Median = middle school |

Two Kruskall-Wallis tests showed that the three groups did not differ for: i) z-scores in the Odd One Out test ($H(2) = 1.197$, $p = .55$); ii) level of education ($H(2) = 0.077$, $p = .96$). On the contrary, the ANOVA test on age was significant ($F(2) = 3.669$, $p = .035$). However, post-hoc tests revealed that no between-group difference reached significance (native vs. early: $p_{tuckey} = .07$; native vs. late: $p_{tuckey} = .06$; early vs. late: $p_{tuckey} = .96$).

### 4.1.2 Materials and procedure

For each sign language, we developed a sentence-to-picture matching task composed by a number of sentences with or without RS. Target sentences with or without RS were preceded by a short narrative and introduced by the verb SAY/TELL. Our investigation focused on the interpretation of the first-person pronoun: all sentences

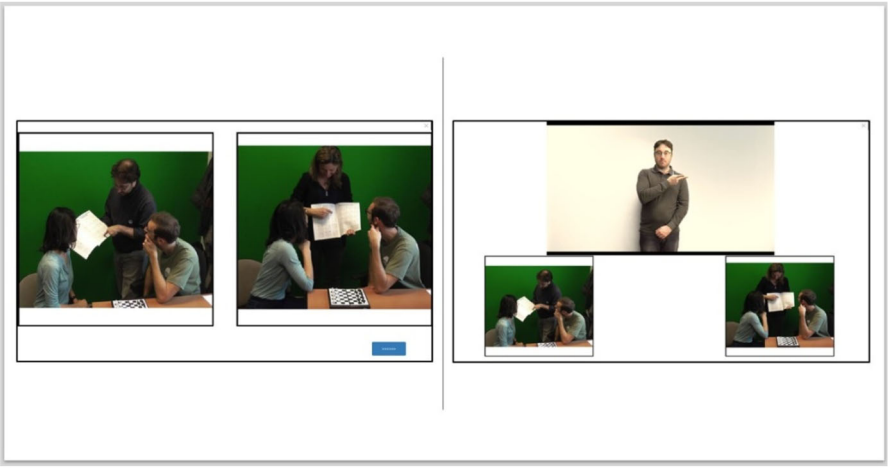


**Fig. 3** Example of a T-SUBJ item. The first screenshot represents the two pictures that could be observed with no time limits. The one on the left matches the sentence without RS, whereas the one on the right matches the sentence with RS. The second screenshot represents the video sentence and the two clickable pictures. Notice that the signer was always the same person and he was clearly recognizable

contained a first-person index ($IX_1$) or an agreeing verb including a first person that shifted under RS. There were three types of sentences: sentences with a transitive verb in which the first-person pronoun was the subject (T-SUBJ), sentences with a transitive verb in which the first-person pronoun was the object (T-OBJ) and copular sentences in which the first-person pronoun was a possessive (C-POSS). A fourth type of sentence was added only in LSC. This condition consisted of sentences without RS, introduced by the verbs READ and SEE. All sentences were videotaped, signed by a deaf native signer (a man for LIS and LSC and a woman for LSF).

The tests were computerized and built using a software specifically developed for the SIGN-HUB Project. The task began with video instructions in either LIS, LSF or LSC. Each item began with two pictures shown side by side on the screen representing two minimally differing alternatives: one picture matched the meaning of the sentence with RS (hence shifted reference of the first-person pronoun), while the other matched the meaning of the sentence without RS, as illustrated in Figs. 3, 4 and 5. Participants could look at the pictures with no time limits. When they felt ready, they pressed an arrow on the bottom-right corner of the screen. In the following slide, the target video was displayed in the middle, with the two pictures still visible right under the video. The video began automatically. After seeing the video utterance, participants had to choose the picture that matched the sentence by clicking on it. Participants were allowed to watch the video only once.

The glosses of all experimental items are listed in the supplementary materials, whereas video materials can be watched online.[10]

Below, we present one example for each condition, taken from the LIS materials:

[10] See https://osf.io/emp6g/.

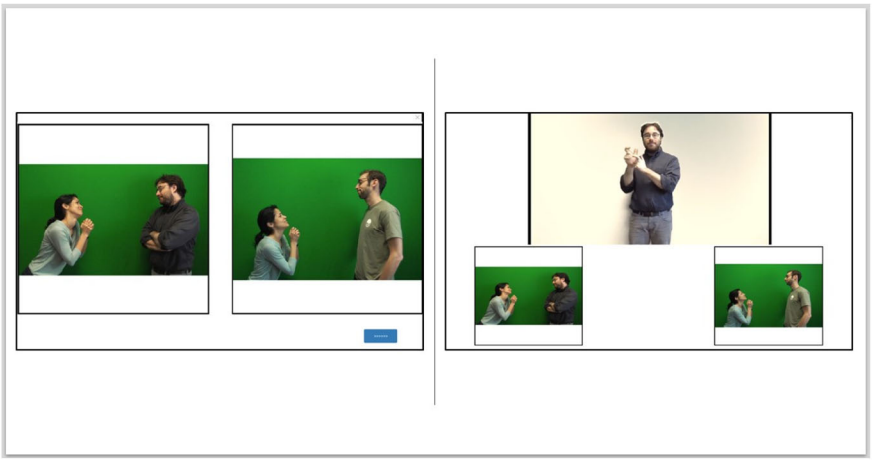


**Fig. 4** Example of a T-OBJ item. Considering the two minimally differing pictures, the one on the left matches the sentence without RS, whereas the one on the right matches the sentence with RS

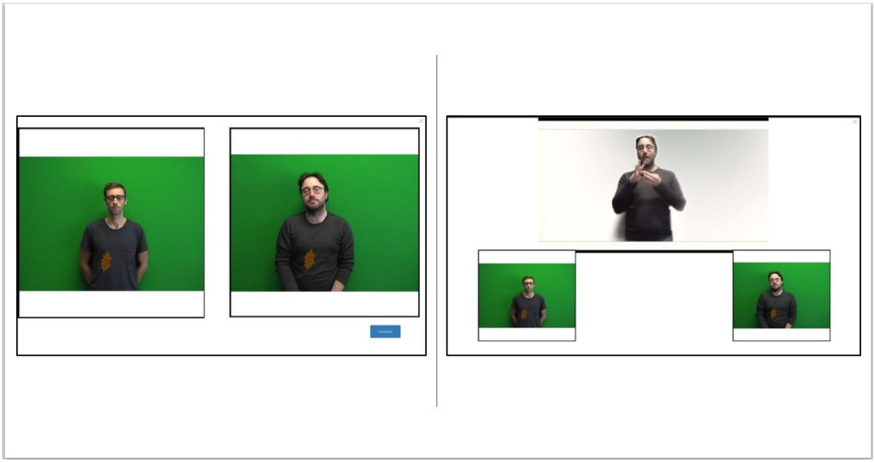


**Fig. 5** Example of a C-POSS item. Considering the two minimally differing pictures, the one on the left matches the sentence with RS, whereas the one on the right matches the sentence without RS

(i) T-SUBJ

(8) With RS

COUSIN++ $IX_{1(poss)}$ $IX_{3pl}$ CHESS LEARN WANT. $AUNT_k$ $IX_3$ TELL $IX_1$ [$_{RS\text{-}k}$ $IX_1$ $CHESS_1$ $TEACH_3$]

'My cousins want to learn to play chess. My aunt told me: I will teach them (how to play).'

(9) Without RS

COUSIN++ $IX_{1(poss)}$ $IX_{3pl}$ CHESS LEARN WANT. AUNT $IX_{1(poss)}$ $IX_3$ TELL $IX_1$ [$_1$TEACH$_3$]

'My cousins want to learn to play chess. My aunt told me to teach them (how to play).'

(ii) T-OBJ

(10) With RS
IX$_1$ FRIEND$_i$ DISCUSS IX$_3$ TELL IX$_1$ [$_{RS\text{-}i}$ GIRLFRIEND IX$_{1(poss)}$ WANT MARRY IX$_1$]
'Talking with a friend he told me: My girlfriend wants to marry me.'

(11) Without RS
FRIEND$_i$ DISCUSS IX$_3$ TELL IX$_1$ GIRLFRIEND IX$_{1(poss)}$ MERRY IX$_1$ WANT
'Talking with a friend he told me that my girlfriend wants to marry me.'

(iii) C-POSS

(12) With RS
TIME-PERIOD EAT FRIEND$_i$ TELL IX$_1$ [$_{RS\text{-}i}$ SHIRT IX(poss)$_1$ STAIN]
'While I was having lunch, a friend of mine told me: My shirt has a stain.'

(13) Without RS
TIME-PERIOD IX$_1$ EAT FRIEND TELL IX$_1$ SHIRT IX (poss)$_1$ STAIN
'While I was having lunch, a friend of mine told me that my shirt had a stain.'

The number of items differed across sign languages. The specific design of each sign language is described below.

This test was one among a set of lexical and syntactic tasks that were developed within the SIGN-HUB Project and the same participants took a number of these tests during the same session. In all languages the RS task was composed of two blocks of about 20 minutes each. The two blocks were separated by at least some hours.

### 4.1.3 Specfic design

**4.1.2.1 Specific design – LIS** Sixteen semantically reversible verbs (8 agreement verbs and 8 plain verbs)[11] were used to create 16 pairs of T-SUBJ sentences and 16 pairs of T-OBJ sentences. As for C-POSS, there were eight pairs of sentences. Each pair in each type of sentence consisted of one sentence with RS (with the first-person pronoun shifted) and one sentence without RS. Experimental items were therefore 80 sentences, 40 with RS and 40 without RS.

The experimental items were divided in two lists of 40 items balanced across type of sentence (16 T-SUBJ, 16 T-OBJ and 8 C-POSS each) and RS condition (20 with RS and 20 without RS). In each list, ten control items were added. Control items were similar in structure to the target items, but with simpler linguistic content, and

[11] "Agreement" and "plain" verbs are two common classes of sign languages verbs. "Agreement verbs" are characterized by a movement between two loci in space associated with two different arguments (e.g. the movement goes from the subject position to the object position), therefore the direction of the movement depend on the position of the arguments. On the contrary, verbs with a fixed movement that cannot be modified depending on the position of their arguments are called "plain verbs" (see Padden 1988; Pfau et al. 2018; a.o.).

they were used to assess participants' attention towards the task. All control items contained a first person indexical and they were all without RS. Participants who responded correctly to less than 75% of control items were removed from the analysis.

Each list, with randomized items, was administered in a different block of about 20 minutes each.

The majority of participants performed the two RS task blocks in the same session, divided by at least three other lexical/syntactic tasks. Some participants were administered the two blocks in two different days.

**4.1.2.2 Specific design – LSF** Twenty-four semantically reversible verbs (12 agreement verbs and 12 plain verbs) were used to create 48 sentences (24 T-SUBJ and 24 T-OBJ sentences). As for C-POSS, there were 12 pairs of sentences. For each condition, half of items were with RS (with the first-person pronoun shifted) and half of them without RS. Experimental items were 60 sentences, 30 with RS and 30 without RS. They were divided in two lists of 36 experimental items balanced across type of sentence and condition (12 T-SUBJ, 12 T-OBJ and 12 C-POSS in each list. The C-POSS sentences were the same in the two blocks, therefore the analysis considered only C-POSS sentences of the first block). In each list, 12 control items were added. As for LIS control items, they were used to assess participants' attention towards the task. Control items were similar in structure to the target items, but with simpler linguistic content. All control items were without RS.

The two lists of items were presented in two different blocks. Items were randomized. All participants received the two blocks in two different days. In each day, the RS task was one among several different lexical and syntactic tasks performed by the participants.

**4.1.2.3 Specific design – LSC** Sixteen semantically reversible verbs (8 agreement verbs and 8 plain verbs) were used to create 16 pairs of T-SUBJ sentences and 16 pairs of T-OBJ sentences. As for C-POSS, there were 10 pairs of sentences. In each condition, each pair consisted of one sentence with RS and one sentence without RS.

A fourth condition was added: it consisted of 16 sentences without RS, introduced by the verbs READ and SEE, which are incompatible with the shifting of indexical pronouns in their complement clause. Eight of them had a subject first-person pronoun and eight an object first-person pronoun. This condition was added as a control, to assess participants' ability to understand subordinate clauses, in contexts where RS is not applicable. Experimental items were therefore 100 sentences. They were divided in two lists of 50 sentences each, balanced across type of sentence and RS condition.

Each list was presented in a different block, with all items randomized. All participants performed the two blocks in the same session, separated by several other syntactic and lexical tasks.

### 4.2 Results and analyses

We present results and analyses for the three languages in different subsections. For LIS and LSF, we performed two analyses: one for sentences with transitive verbs with

subject or object pronouns and one for copular sentences with a possessive pronoun. For LSC, these two analyses were preceded by an analysis of subordinate clauses without RS.

We detected outlier participants with the following procedure: for each sign language, we calculated by subject mean accuracy in all target items (T-OBJ, T-SUBJ and C-POSS). We then calculated by group mean of the means and standard deviations. Participants whose mean accuracy was more than 2.5 SDs below the mean of the means were excluded.

All analyses were conducted with the statistical software R. In the logistic regression analysis, performed using the glmer function (family = "binomial") of the lme4 package (Bates et al. 2015), we tested fixed factors inclusion in the final model with a series of likelihood ratio tests, and we progressively removed the factors that did not significantly increase the overall model's goodness of fit (Gelman and Hill 2006).

Besides the experimental conditions, in all analyses we entered in the model the fixed predictor age. We did not consider education level because in all language groups the two factors were significantly correlated (negative correlation: the higher the level of education, the younger the participant. LIS: tau $= -0.42$, $p = .001$; LSF: tau $= -0.30$, $p = .02$; LSC: tau $= -0.41$, $p = .001$).

Here, for each analysis, we report only the best fitting model. Supplementary materials contain all the analyses, whereas related R scripts are stored on OSF.[12]

#### 4.2.1 LIS

All participants performed well in control items (min 80% correct, max 100% correct) and no one was classified as outlier, therefore no participant was removed.

Four items (two T-OBJ and two T-SUBJ) were removed because of overall low accuracy due to design issues.

**4.2.1.1 Sentences with transitive verb with subject or object pronouns in LIS** Results are represented in Fig. 6. The + sign indicates the group mean, whereas the line inside the box is the median. Overall, native signers performed better than early and late signers. Sentences with RS appear to be more difficult (lower accuracy) in T-OBJ sentences, whereas the opposite pattern seems to emerge in T-SUBJ sentences, at least for native and early signers.

We analyzed accuracy (dichotomous variable) by means of mixed models logistic regression. As fixed factors, we considered group (ref. level = native, vs. early vs. late), type of sentence (T-SUBJ vs. T-OBJ), condition (no RS vs. RS), and their interactions (including the three-way interaction). We also added age (mean centered) and block (first or second). As random factors, we entered into the model intercepts for subjects and items, as well as by-subject slopes for the effect of condition and by-item slopes for the effect of group and condition and their interaction. The best fitting model was the one including group, the interaction between type of sentence and condition and the main effect of age. To understand the interaction, we performed pairwise comparisons of type of sentence per condition. Moreover, we performed

[12] See https://osf.io/emp6g/.

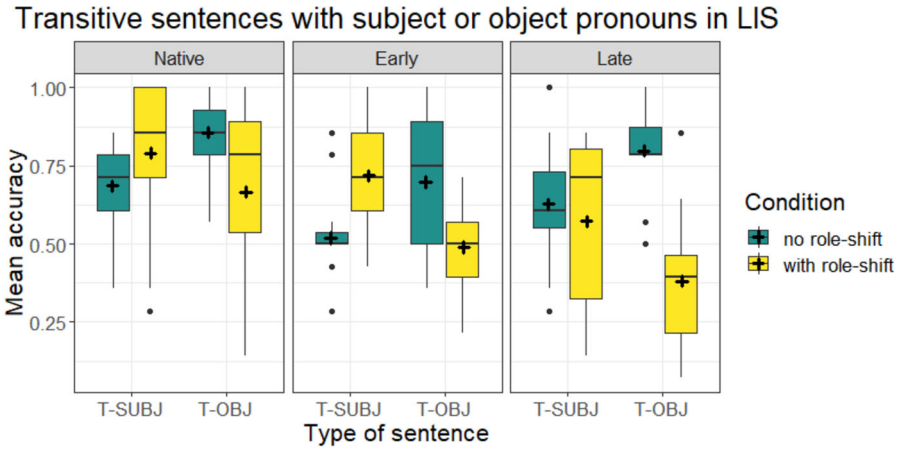



**Fig. 6** Boxplots representing the distribution of subjects' mean accuracy in sentences with transitive verb in LIS with subject or object pronouns, by condition and by group. The + sign indicates the group mean, whereas the line inside the box indicates the median

**Table 4** Mixed models logistic regression analysis of accuracy in T-SUBJ and T-OBJ sentences in LIS including pairwise comparison results. Estimate ($\beta$), standard error (SE), z value and p for the fixed effects. Significant p-values are in bold

| Fixed factor | $\beta$ | SE | z value | $p$ |
|---|---|---|---|---|
| Type of sentence x Condition | −1.90 | 0.38 | −4.95 | ***<.0001*** |
| Condition (no RS vs. RS in T-SUBJ sentences) | 0.55 | 0.37 | 1.48 | *.14* |
| Condition (no RS vs. RS in T-OBJ sentences) | −1.36 | 0.37 | −3.67 | ***.0002*** |
| Type of sentence (T-SUBJ vs. T-OBJ in sentences without RS) | 0.85 | 0.22 | 3.80 | ***.0001*** |
| Type of sentence (T-SUBJ vs. T-OBJ in sentences with RS) | −1.05 | 0.23 | −4.49 | ***<.0001*** |
| Group (Native vs. Early) | −0.88 | 0.21 | −4.12 | ***<.0001*** |
| Group (Native vs. Late) | −0.60 | 0.23 | −2.62 | ***.009*** |
| Group (Early vs. Late) | 0.28 | 0.20 | 1.39 | *.16* |
| Age | −0.03 | 0.01 | −3.42 | ***.0006*** |

pairwise comparisons of group to compare the performances of all three groups. Final results are reported in Table 4.

The analysis confirmed that native signers outperformed early and late signers in all types of sentences and conditions. The RS condition was more difficult than no RS condition in T-OBJ sentences. Between the two types of sentences, there was an asymmetry: in the no RS condition, T-OBJ sentences were more accurate than T-SUBJ sentences. In the RS condition, it was the opposite (T-OBJ less accurate than T-SUBJ). Note also that overall accuracy decreased as chronological age increased.

**4.2.1.2 Copular sentences with a possessive pronoun in LIS** C-POSS sentences results are depicted in Fig. 7, representing the distribution of subjects' mean accuracy in copular sentences in LIS by group and condition. The + sign indicates the group

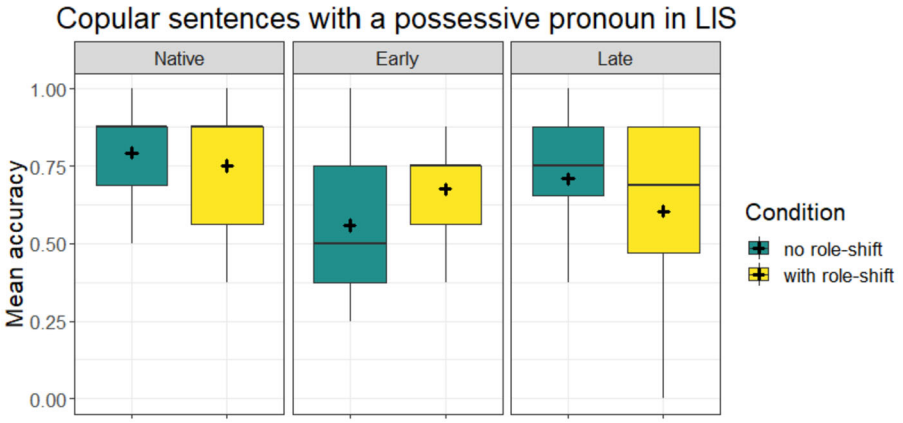



**Fig. 7** Boxplots representing the distribution of subjects' mean accuracy in copular sentences in LIS by group and condition. The + sign indicates the group mean, whereas the line inside the box indicates the median

**Table 5** Mixed models logistic regression analysis of accuracy in C-POSS sentences in LIS. Estimate ($\beta$), standard error (SE), z value and p for the fixed effects of the final model and pairwise comparison of group. Significant p-values are in bold

| Fixed factor | $\beta$ | SE | z value | $p$ |
|---|---|---|---|---|
| Group (Native vs. Early) | −0.72 | 0.24 | −3.01 | ***.003*** |
| Group (Native vs. Late) | −0.30 | 0.28 | −1.07 | *.29* |
| Group (Early vs. Late) | −0.43 | 0.26 | −1.68 | *.09* |
| Age | −0.04 | 0.12 | −3.78 | ***.0002*** |
| Block | 0.99 | 0.39 | 2.56 | ***.01*** |

mean, whereas the line inside the box indicates the median. It appears that the performance of native signers was not affected by the RS condition, whereas early signers performed slightly better in sentences with RS than in sentences without RS. The situation is the opposite in late signers.

The dichotomous variable accuracy was analyzed by means of mixed effects logistic regression. As fixed factors, we considered group (native vs. early vs. late), condition (no RS vs. RS), their interaction, chronological age (mean centered) and block (first/second). We entered into the model random intercepts for subjects and items, as well as by-subject random slopes for the effect of condition and by-item random slopes for the effect of group and condition and their interaction. The best fitting model was the one including group and age: native signers significantly outperformed early signers, whereas the difference between native and late signers was not significant. Pairwise comparisons of groups showed that accuracy did not significantly differ between early and late signers (Table 5). Accuracy decreased as chronological age increased and increased from the first to the second block.

### 4.2.2 LSF

One participant (LSF-40, late group) did not meet the criterion of 75% accuracy in control items and was removed from the analysis. Two items (one T-OBJ and

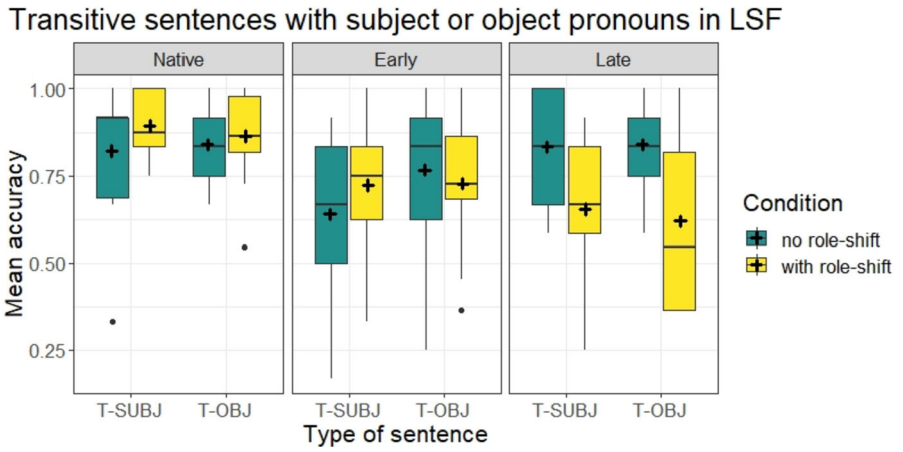



**Fig. 8** Boxplots representing the distribution of subjects' mean accuracy in sentences with transitive verb in LSF with subject or object pronouns, by condition and by group. The + sign indicates the group mean, whereas the line inside the box indicates the median

one C-POSS) were removed because of design issues, resulting in very low general accuracy.

**4.2.2.1 Sentences with transitive verb with subject or object pronouns in LSF** As Fig. 8 shows, performance of native signers was better than that of early and late signers. Native and early signers did not show a clear difference between sentences with RS and sentences without RS. In the late signers group, sentences with RS appear to be harder.

We performed a mixed effects logistic regression analysis of accuracy (dichotomous variable). Fixed factors were group (native vs. early vs. late), type of sentence (T-OBJ vs. T-SUBJ), condition (no RS vs. RS), their interactions (included the three-ways interaction), age (mean centered) and block (first/second). We entered into the model random intercepts for subjects and items, as well as by-subject random slopes for the effect of condition and by-item random slopes for the effect of group. The best fitting model was the one including the interaction between group and condition, and block (Table 6).

The analysis shows that native signers performed better than early signers in all types of sentences and conditions, and better than late signers only in the RS condition. Moreover, the difference between early and late signers was not significant considering sentences with RS, but late signers outperformed early signers in sentences without RS. In late signers, the performance in the RS condition was worse than that in the no RS condition. Overall performance increased from the first to the second block.

**4.2.2.2 Copular sentences with a possessive pronoun in LSF** Looking at the results reported in Fig. 9, it seems that, overall, native signers performed better than early and late signers. Moreover, in native and early signers, accuracy was higher in sentences

**Table 6** Mixed models logistic regression analysis of accuracy in T-SUBJ and T-OBJ sentences in LSF, including pairwise comparisons. Estimate ($\beta$), standard error (SE), z value and p for the fixed effects of the final model. Significant p-values are in bold

| Fixed factor | $\beta$ | SE | z value | $p$ |
|---|---|---|---|---|
| Condition x Group (Native vs. Early) | −0.27 | 0.57 | −0.47 | *.64* |
| Condition x Group (Native vs. Late) | −1.63 | 0.59 | −2.77 | ***.006*** |
| Condition (no RS vs. RS, Native) | 0.30 | 0.51 | 0.60 | *.55* |
| Condition (no RS vs. RS, Early) | 0.04 | 0.42 | 0.09 | *.92* |
| Condition (no RS vs. RS, Late) | −1.32 | 0.48 | −2.74 | ***.006*** |
| Group (Native vs. Early, no RS) | −0.97 | 0.41 | −2.39 | ***.017*** |
| Group (Native vs. Late, no RS) | −0.09 | 0.43 | −0.22 | *.83* |
| Group (Early vs. Late, no RS) | 0.88 | 0.41 | 2.13 | ***.033*** |
| Group (Native vs. Early, RS) | −1.24 | 0.40 | −3.06 | ***.002*** |
| Group (Native vs. Late, RS) | −1.72 | 0.41 | −4.18 | ***<.0001*** |
| Group (Early vs. Late, RS) | −0.48 | 0.38 | −1.25 | *.21* |
| Block | 0.62 | 0.26 | 2.35 | ***.019*** |

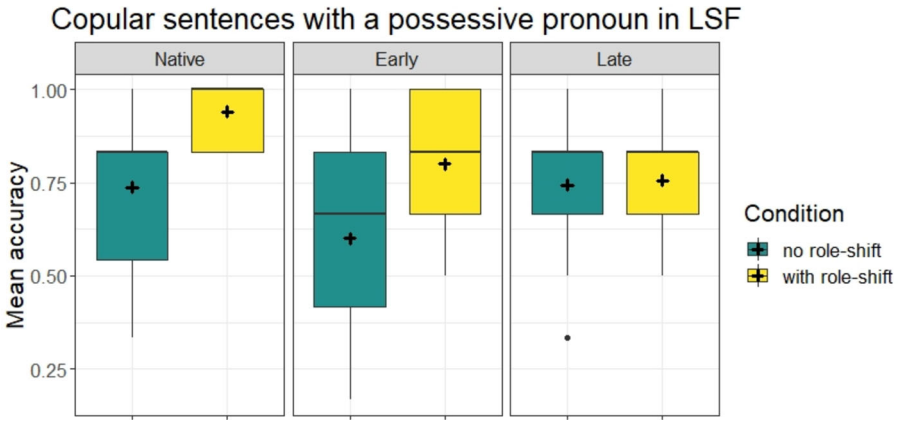



**Fig. 9** Boxplots representing the distribution of subjects' mean accuracy in copular sentences in LSF by group and condition. The + sign indicates the group mean, whereas the line inside the box the median

with RS compared to sentences without RS, whereas the same does not hold true for late signers.

We performed a mixed models logistic regression analysis of accuracy. Group (native vs. early vs. late), condition (no RS vs. RS), their interaction, and age (mean centered) were entered in the model as fixed factors. We added random intercepts for subjects and items, as well as by-subject random slopes for the effect of condition and by-item random slopes for the effect of group. The best fitting model was the one including the interaction between group and condition (Table 7 and Fig. 9).

**Table 7** Mixed models logistic regression analysis of accuracy in C-POSS sentences in LSF. Estimate ($\beta$), standard error (SE), z value and p for the fixed effects of the final model. Significant p-values are in bold

| Fixed factor | $\beta$ | SE | z value | $p$ |
|---|---|---|---|---|
| Condition x Group (Native vs. Early) | −0.66 | 0.86 | −0.77 | *.44* |
| Condition x Group (Native vs. Late) | −1.83 | 0.80 | −2.29 | ***.02*** |
| Condition (no RS vs. RS, Native) | 1.68 | 0.89 | 1.90 | *.06* |
| Condition (no RS vs. RS, Early) | 1.02 | 0.59 | 1.72 | *.09* |
| Condition (no RS vs. RS, Late) | −0.15 | 0.78 | −0.19 | *.85* |
| Group (Native vs. Early, no RS) | −0.99 | 0.59 | −1.68 | *.09* |
| Group (Native vs. Late, no RS) | 0.01 | 0.57 | 0.02 | *.98* |
| Group (Early vs. Late, no RS) | 1.00 | 0.61 | 1.64 | *.10* |
| Group (Native vs. Early, RS) | −1.65 | 0.65 | −2.55 | ***.01*** |
| Group (Native vs. Late, RS) | −1.82 | 0.60 | 3.03 | ***.002*** |
| Group (Early vs. Late, RS) | −0.17 | 0.52 | −0.32 | *.75* |

The analysis shows that native signers outperformed early and late signers in the RS condition only. The observed difference between sentences with RS and sentences without RS in native and early signers did not reach significance.

### 4.2.3 LSC

No participant was classified as an outlier; therefore, no participant was removed. Three items (2 C-POSS) were removed because of design issues.

**4.2.3.1 Subordinate clauses comprehension in LSC** As depicted in Fig. 10, overall accuracy in simple subordinate clauses was good for native and early signers, and almost good for late signers, with no visible difference between subordinate clauses introduced by the attitude verb SAY (T-OBJ and T-SUBJ sentences in the no RS condition) and those introduced by READ and SEE.

To confirm our observations, we ran a GLMMs analysis of accuracy. Group (native vs. early vs. late), condition (sentences with SAY vs. sentences with READ/SEE), their interaction, age (mean centered) and block (first/second) were entered in the model as fixed factors. Random intercepts for subjects and items, as well as by-subject random slopes for the effect of condition and by-item random slopes for the effect of group were added. The best fitting model was that with group and block as fixed predictors (see Table 8). The difference in accuracy between native and early signers was not significant, whereas both native and early signers significantly outperformed late signers. Overall performance was better in the second compared to the first block. Importantly, there was no significant difference between sentences introduced by SAY in the no RS condition and those introduced by READ/SEE.

**4.2.3.2 Sentences with transitive verb with subject or object pronouns in LSC** Figure 11 shows by group overall mean accuracy in T-OBJ and T-SUBJ sentences with

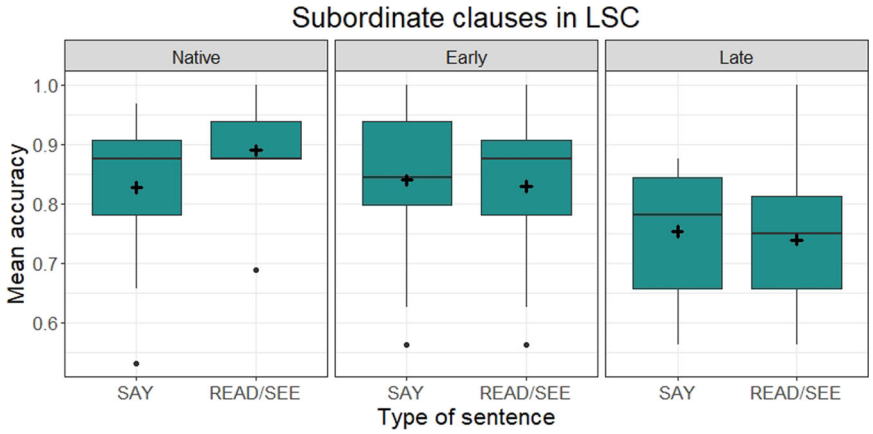



**Fig. 10** Boxplots representing the by group distribution of participants' mean accuracy in subordinate clauses introduced by the verb SAY in the no RS condition (x-axis = SAY) or by the verbs READ/SEE (x-axis = READ/SEE). The + sign indicates the group mean, whereas the line inside the box indicates the median

**Table 8** Mixed models logistic regression analysis of accuracy subordinate clauses in LSC. Estimate ($\beta$), standard error (SE), z value and p for the fixed effects of the final model. Significant p-values are in bold

| Fixed factor | $\beta$ | SE | z value | $p$ |
|---|---|---|---|---|
| Group (Native vs. Early) | −0.09 | 0.36 | −0.24 | *.81* |
| Group (Native vs. Late) | −0.84 | 0.36 | −2.33 | ***.02*** |
| Group (Early vs. Late) | −0.75 | 0.35 | −2.14 | ***.03*** |
| Block | 0.36 | 0.17 | 2.08 | ***.04*** |

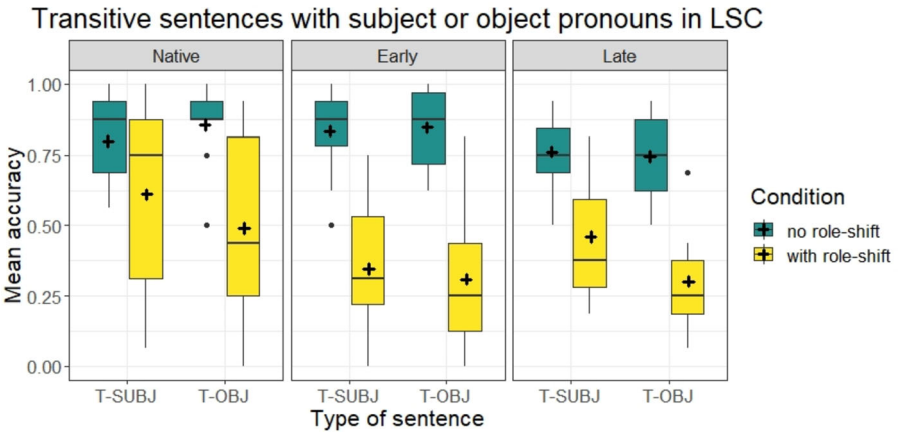



**Fig. 11** Six boxplots representing the distribution of subjects' mean accuracy in sentences with transitive verbs in LSC (T-OBJ and T-SUBJ) by condition (no RS in green and RS in yellow) and by group

and without RS. It is evident that all groups have a good performance in sentences without RS. On the contrary, the performance in sentences with RS is more variable and poorer in the native signers, and very poor in early and late signers.

**Table 9** Mixed models logistic regression analysis of accuracy in T-SUBJ and T-OBJ sentences in LSC. Estimate ($\beta$), standard error (SE), z value and p for the fixed effects of the final model and pairwise comparisons. Significant p-values are in bold

| Fixed factor | $\beta$ | SE | z value | $p$ |
|---|---|---|---|---|
| Condition x Group (Native vs. Early) | −1.39 | 0.65 | −2.13 | ***.033*** |
| Condition x Group (Native vs. Late) | −0.30 | 0.69 | −0.44 | *.66* |
| Condition (no RS vs. RS, Native) | −1.66 | 0.56 | −2.98 | ***.003*** |
| Condition (no RS vs. RS, Early) | −3.05 | 0.53 | −5.75 | ***<.0001*** |
| Condition (no RS vs. RS, Late) | −1.96 | 0.58 | −3.38 | ***.0007*** |
| Group (Native vs. Early, no RS) | 0.34 | 0.39 | 0.88 | *.38* |
| Group (Native vs. Late, no RS) | −0.35 | 0.41 | −0.87 | *.38* |
| Group (Early vs. Late, no RS) | −0.69 | 0.38 | −1.82 | *.07* |
| Group (Native vs. Early, RS) | −1.05 | 0.46 | −2.26 | ***.02*** |
| Group (Native vs. Late, RS) | −0.66 | 0.50 | 1.32 | *.19* |
| Group (Early vs. Late, RS) | 0.39 | 0.47 | 0.83 | *.41* |
| Age | −0.03 | 0.01 | −2.37 | ***.018*** |

Accuracy was analyzed by means of mixed effects logistic regression. As fixed factors, we entered into the model group (ref. level = native vs. early vs. late), type of sentence (T-SUBJ vs. T-OBJ) condition (no RS vs. RS), their interactions (included the three-ways interaction), age (mean centered) and block (first/second). As random factors, we added intercepts for subjects and items, as well as by-subject and by-items slopes for the effect of condition. The best fitting model was the one including group and the interaction between group and condition. Results with pairwise comparisons of group per condition, are reported in Table 9.

To summarize, accuracy in T-SUBJ and T-OBJ sentences was significantly lower in the RS condition compared to no RS condition in all groups. In the RS condition, native signers outperformed early signers, whereas the difference between native and late signers was not significant. Overall, accuracy decreased as chronological age increased.

**4.2.3.3 Copular sentences with a possessive pronoun in LSC** Contrary to T-SUBJ and T-OBJ sentences, in C-POSS sentences accuracy was not extremely lower in sentences with RS compared to sentences without RS. In late signers, performance looks higher in sentences with RS compared to sentences without RS (Fig. 12). Overall, performance of native signers seems slightly better than performance in the other two groups.

Accuracy was analyzed with mixed effects logistic regression. Fixed factors were group (native vs. early vs. late), condition (no RS vs. RS), their interaction, age (mean centered) and block. We entered into the model random intercepts for subjects and items, as well as by-subject random slopes for the effect of condition. The best fitting model was the one including age: accuracy decreased as age increased ($\beta = -0.03$, SE $= 0.01$, $z = -3.16$, $p = .002$).

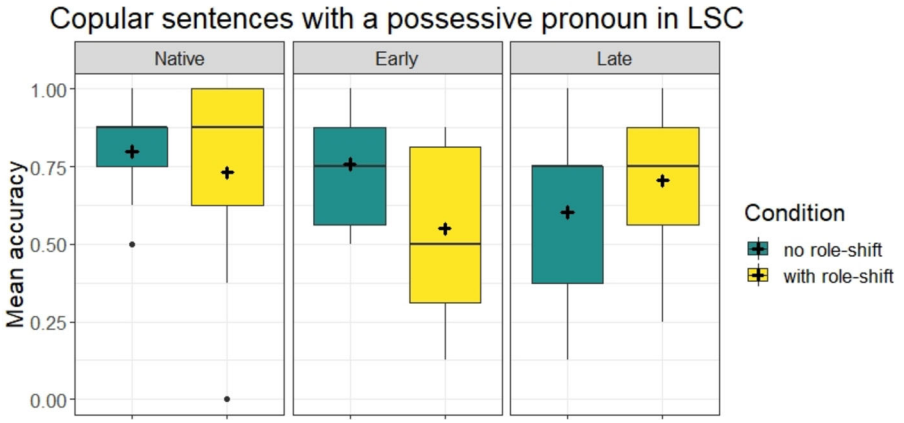



**Fig. 12** Boxplots representing the distribution of subjects' mean accuracy in copular sentences in LSC by group and condition. The + sign indicates the group mean, whereas the line inside the box indicates the median

#### 4.2.4 Brief summary of the results

Let us briefly summarize the main findings: in LIS we found an asymmetry between T-SUBJ and T-OBJ sentences, with higher accuracy in T-OBJ compared to T-SUBJ in the no RS condition and higher accuracy in T-SUBJ compared to T-OBJ in the RS condition. In T-OBJ sentences, RS condition was more difficult than no RS condition. Moreover, native signers always outperformed early signers, whereas they outperformed late signers in T-SUBJ and in T-OBJ sentences, but not in C-POSS sentences.

In LSF, we found an effect of RS only in T-SUBJ and T-OBJ sentences and only in late signers, who performed worse in the RS condition compared to the no RS condition. Moreover, native signers outperformed early signers in all types of T-SUBJ and T-OBJ sentences, and in C-POSS sentences with RS. Native signers also outperformed late signers in all sentences with RS.

In LSC, considering simple subordinate clauses all together, both native and early signers outperformed late signers. Considering T-SUBJ and T-OBJ sentences, accuracy was lower in the RS compared to the no RS condition. We found an effect of group only considering T-SUBJ and T-OBJ sentences with RS comparing native and early signers. We should stress, however, that in T-SUBJ and T-OBJ sentences with RS the performance of many native signers was very poor, at chance level or below chance level. Neither effect of group nor condition was found in C-POSS sentences.

All in all, accuracy decreased as chronological age increased (chronological age was a significant predictor in LIS and in LSC, except for LSC subordinate clause without RS analysis).[13]

[13] In a behavioral task assessing accuracy but not reaction times, chronological age effects might be unexpected. However, as we briefly discussed in Sect. 4.2, it turned out that chronological age and education were negatively and significantly correlated in our participants, therefore in considering the reported chronological age effects, we should have in mind that the older participants were also the less educated.

In C-POSS sentences in LIS, in T-SUBJ and T-OBJ sentences in LSF and in subordinate clause without RS in LSC we found an effect of blocks, with significantly higher accuracy in the second block compared to the first block.

## 5 Discussion

In our study, sentences without RS are never found to be significantly less accurate than sentences with RS. This is true across all languages, conditions, and groups.

In LSC a lower accuracy in sentences with RS compared to sentences without RS was found in all groups. However, as we said in the previous section, in T-SUBJ and T-OBJ sentences with RS the performance of many native signers was very poor. For this reason, we discuss LSC results separately in Sect. 5.1.

As for LSF, we found lower accuracy in sentences with RS compared to sentences without RS only in late signers. This effect was found in LIS only considering T-OBJ stimuli. Specifically, among sentences in which the first-person pronoun is in object position, those containing RS were significantly more difficult than sentences without RS. Interestingly, no difference between T-SUBJ and T-OBJ sentences was found in LSF. We shall argue in Sect. 5.2 that these results support the theoretical approach of RS involving a complement clause hosting a context-shifting operator, as discussed.

Finally, age of exposure effects are discussed in Sect. 5.3.

### 5.1 Role shift in LSC

In LSC, the performance in T-SUBJ and T-OBJ sentences with RS was overall poorer than in sentences without RS, and this is in line with what we found in the other languages. In LSC, however, even the performance of native signers was very poor and very variable in the RS condition, and this calls for a specific discussion. Interestingly enough this was not the case for copular sentences C-POSS, where sentence accuracy was actually good and not lower in sentences with RS compared to sentences without RS. In this section we are going to discuss some factors that might have affected the performance in the LSC experiment.

In principle, the different performance in LSC might be due to grammatical differences between this language and LIS and LSF as far as RS is concerned. Although we cannot exclude this possibility, we think an explanation of the low performance in LSC has to do with the experimental stimuli we used.

The first factor is NMMs: in LSC RS stimuli, while head lean or shift and change of direction of the eye gaze were consistently present to mark RS, this was not the case for body shift. Body shift was often realized with a soft turning of the body (Fig. 13) or it was absent. This might have increased the difficulty in detecting the presence of RS in a sentence. The realization of NMMs was the same across conditions, so this can justify the overall lower performance in sentences with RS, even

Then, further factors that we did not consider might have played a role, e.g. participants' occupation and their relationship with technologies. We might speculate that older participants with a low level of education were less likely to spend much time using computers, and our test was computer-based. Of course, we acknowledge that this is just a conjecture.

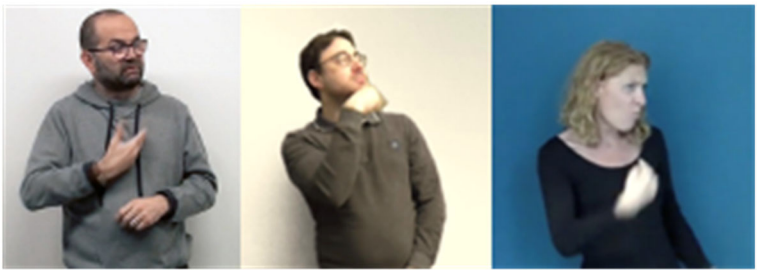


**Fig. 13** Body shift in RS sentences in LSC (soft realization), LIS and LSF (marked realization)

though this does not clearly explain why in copular sentences the performance in detecting RS was not affected as much.

This mild realization of NMMs in the LSC stimuli, and the possible weak perception of these markers across participants, appear to confirm the hypothesis of the gradient nature of NMMs in sign languages proposed by Davidson (2013) and Davidson and Mayberry (2015). We shall go back to this hypothesis in Sect. 5.2. Notice that in LIS and LSF body shift was systematically and clearly realized. These cross-linguistic differences were not included in the initial design, but were naturally introduced by our informants who signed the sentences in a way that was most natural to them.

Another aspect that might have triggered a lower performance in RS sentences in LSC is the design of the test itself. Differently from in LIS and LSF, in LSC there was a fourth condition where participants saw a group of sentences without RS introduced by the verbs SEE or READ. The participants were thus exposed to a higher number of subordinate clauses without RS, than to clauses with RS, and this unbalanced design might have biased the signers towards a noRS interpretation.

If we now give a closer look at the complexity of the stimuli, the design of the test could also explain why participants performed more poorly in RS compared to noRS in T-SUB/OBJ stimuli, but not in C-POSS stimuli. By design, C-POSS had a simpler syntactic structure due to the copular construction.

In conclusion, while a performance in RS sentences might have been overall higher if stimuli had more marked NMMs and if the number of stimuli were more balanced between RS and noRS condition, the different pattern between T-SUBJ/OBJ and C-POSS sentences can be explained by saying that the latter are cognitively less demanding than the former one.

### 5.2 Role shift in LIS and LSF

Summarizing once more, we found that sentences with RS were in general less accurately comprehended than sentences without RS. Moreover, an intriguing and prima facie puzzling finding emerged from our study, namely the fact that in LIS, and only in LIS, there was a complex subject-object asymmetry: RS sentences in which the first-person pronoun is in object position displayed more errors than RS sentences in which it is in subject position. However, the opposite pattern was observed in sentences without RS: sentences in which the first-person pronoun is in object position

were better comprehended. This data pattern was not found in LSF. Two questions arise: what is the source of this complex pattern in LIS? And why was it not observed in LSF?

To explain this pattern, we took into consideration three factors. The first has to do with the degree in which NMMs are visible in our experimental data. Suppose that, contrary to what is assumed in much literature on the topic (but in line with what is proposed by Davidson 2013 and Davidson and Mayberry 2015), NMMs, including those signaling RS, are gradient as opposed to categorical, unlike, say, complementizers, which, when present, unambiguously indicate subordination. If so, the poorer performance in RS sentences could be attributed to the failure to recognize the correct NMMs, especially, but not uniquely, by non-native signers. While this explanation might contribute to explain the LSC data, as we mentioned in Sect. 5.1, we believe that it does not extend to LIS and LSF. First, although in spontaneous signing the markers of RS can be very subtle, especially if the preceding discourse context favors the RS interpretation, this was not the case in LIS and LSF experimental stimuli, where body-shift was clearly visible (see Fig. 13 to get an idea. The reader can also inspect all video materials at the OSF repository webpage). Furthermore, this factor alone cannot explain the subject-object asymmetry (when present).

A second element that we considered is the potential role of the linguistic context that introduces the experimental sentence, which might bias or not a RS interpretation. When building the experimental stimuli we tried to use the same contexts across the experiments when possible. This allowed us to look at those introductory contexts that were nearly identical in LIS and LSF. If the contexts alone were able to determine the RS/noRS interpretation of the relevant sentence, we would expect signers to give the same response across the two languages. But this is not what we observe: it emerges that signers have a different performance in the two languages, along the lines summarized above, even by restricting the analysis to these invariant contexts.[14] So, the differences in the linguistic material introducing the RS/noRS sentences is not likely to explain the cross-linguistic differences between LIS and LSF.

We believe that a third factor is the key to understand the pattern of results and this is the presence of other pointing signs, in addition to the indexical that undergoes RS. In LIS, out of the sixteen T-OBJ sentences with RS, eight have a pointing sign in the subject position (these are sentences 2, 4, 6, 11, 12, 13, 14 and 16; note that the second pointing sign was not planned in the original design of the experiment, but it was spontaneously introduced by the consultant who was videotaped). In these eight sentences, the pointing sign can be of two types. In some, exemplified by (14), it is a possessive pronoun contained within the subject NP ('my girlfriend').

[14]We report here the pairs of sentences that have invariant contexts. In each pair, the first number corresponds to an LSF sentence, while the second one corresponds to an LIS sentence. T-SUB sentences: 01-RS/04-RS, 03-RS/01-RS, 04-RS/16-RS, 05-RS/10-RS, 13-NRS/3-NRS, 14-NRS/07-NRS, 15-NRS/2-NRS, 16-NRS/12-NRS, 20-NRS/6-NRS; T-OBJ sentences: 04-RS/16-RS, 05-RS/10-RS, 06-RS/11-RS, 13-NRS/3-NRS, 14-NRS/7-NRS, 15-NRS/2-NRS, 16-NRS/12-NRS, 20-NRS/6-NRS and 23-NRS/14-NRS; C-POSS: 01-RS/01-RS, 02-RS/02-RS, 04-RS/03-RS, 05-RS/04-RS, 08-NRS/05-NRS and 09-NRS/06-NRS.

**Table 10** Performance of RS T-OBJ sentences involving pointing and no pointing sign in subject position in LIS

| | Mean | SD |
|---|---|---|
| 'Pointing sign in the subject position' | 0.47 | 0.50 |
| 'No pointing sign in the subject position' | 0.60 | 0.49 |

(14) $IX_1$ $FRIEND_i$ DISCUSS $IX_3$ TELL $IX_1$ [$_{RS}$ GIRLFRIEND $IX_{1(poss)}$ WANT MARRY $IX_1$]
'Talking with a friend he told me: My girlfriend wants to marry me.'

In other sentences, like (15), the pointing sign is an index doubling the subject NP ('secretary'; note that doubling by a pointing sign is very common for signs articulated on the body in LIS and this index was thus spontaneously produced by our informants because it made the sentence look more natural).

(15) OFFICE INSIDE $COLLEAGUE_i$ TELL $IX_1$ [TOMORROW $SECRETARY_i$ $IX_i$ $FOLDER_i$$GIVE_{\underline{1}}$]
'In the office a colleague told me: Tomorrow the secretary will give me a folder.'

In (14) the possessive pronoun and the object pronoun are both directly referential expressions, therefore under RS they are interpreted with respect to the context of the reported speech. In (15) the pointing sign is not deictic. However, it identifies a locus in the signing space which is later picked up by the directional verb GIVE and this identification is indirectly influenced by context shift: as a matter of fact, without RS the pointing sign in subject position is interpreted as a third person pronoun with respect to the actual signer, but with RS it is interpreted as a third person pronoun with respect to the shifted subject of the verb of saying.

There is evidence showing that the presence of a pointing sign in the subject position complicates the sentences. Descriptive data (overall mean accuracy and SD) show a lower performance on RS T-OBJ sentences with a pointing sign in the subject position than in the other sentences, as Table 10 shows.[15]

Furthermore, the presence of a pointing sign in the subject position impacts selectively the three groups of signers, as expected if this creates a linguistic difficulty that is more challenging for special populations (see Table 11). No effect whatsoever is observed with native signers (67% accuracy in both types of sentences), a degradation when the pointing sign is present is already visible with early signers (57% as opposed to 44% accuracy) and is at its peak with late signers (54% accuracy as opposed to 26% accuracy):

We hypothesize that the degradation in T-OBJ sentences with a pointing sign in subject position is due to an intervention effect similar to the one observed in ob-

[15]Sentences without intervention are T-OBJ sentences 1, 3, 5, 7, 8, 9, 10 and 15. As we mentioned in 4.2.1, before running the analysis we removed two T-OBJ sentences because of design issues. The two removed T-OBJ sentences are numbers 3 and 7, both now classified as "without intervention." To be thorough, we checked if the observed jump in accuracy from sentences with intervention to sentences without intervention occurs if we consider also these 2 eliminated items, and the answer is yes (overall mean accuracy including all 8 T-OBJ sentences is 0.58 (SD=0.49)).

**Table 11** Performance of three groups in LIS RS T-OBJ sentences involving the presence/absence of a pointing sign in the subject position

| | Mean | SD |
|---|---|---|
| NATIVE SIGNERS | | |
| 'Pointing sign in the subject position' | 0.67 | 0.47 |
| 'No pointing sign in the subject position' | 0.67 | 0.47 |
| EARLY SIGNERS | | |
| 'Pointing sign in the subject position' | 0.44 | 0.50 |
| 'No pointing sign in the subject position' | 0.57 | 0.50 |
| LATE SIGNERS | | |
| 'Pointing sign in the subject position' | 0.26 | 0.44 |
| 'No pointing sign in the subject position' | 0.54 | 0.50 |

ject *wh*-dependencies. A well-established explanation for the difficulty of object *wh*-dependencies in questions or relative clauses is that in sentences like (17) the subject intervenes between the *wh*-operator and its variable, while no similar intervention is observed in subject dependencies like (16). Of course, this approach must specify what counts as an intervener. Friedmann et al. (2009) propose a formalization in terms of featural similarity, which captures the fact that intervention arises only if the intervener shares a number of grammatical features with the category that has moved (intervention is defined in structural terms, namely Y intervenes between X and Z if X c-commands Y and Y c-commands Z). For example, no intervention is observed if the intervening subject does not have a lexical restriction while the moved category does. This is illustrated in (18). Similarly, if there is a mismatch in number features between the moved category and the subject intervener, as in (19), the intervention effect is much weaker (Adani et al. 2010).

(16) The activist that __ attacked the journalist.

(17) The activist that the journalist attacked __.

(18) The activist that he attacked __.

(19) The activist that the journalists attacked __.

Extending the intervention explanation from *wh*-dependencies to RS is not entirely obvious, as the context-shifting operator may seem very different from the operator of relatives and interrogatives. However, at least under certain analyses this is possible. For example, under Schlenker's (2003) analysis, context shift is due to a dependency between the operator and the variable introduced by the indexical. Therefore, the operator does entertain a long-distance dependency, and, if this dependency is represented in a syntactic configuration, it is expected to be affected by intervention. Following Quer (2005), we assume that the context-shifting operator is indeed represented in syntax, as it is hosted in a dedicated position in the CP area.[16] It qualifies as such as an A-bar operator, a class of operators which is known to participate to weak island effects, precisely those effects that can be explained in terms of interven-

[16]More specifically, Quer (2005) proposes that, in attitude RS sentences, the context-shifting operator sits in the Speech Act Phrase and moves by head movement incorporating into the propositional attitude verb.

tion (see Szabolcsi 2006 for an overview). As for the link between the interpretative properties of RS (including the shifted interpretation of indexicals) and its morpho-phonological properties (the specific non-manual marking co-occurring with the lexical material undergoing RS), we follow Quer, who proposes that the material in the c-command domain of the contex-shifting operator materializes in a dedicated non-manual morphology by analogy with what happens with Wh, Q or Neg operators in sign languages (cf. Neidle et al. 2000 for an analysis of NMMs along these lines).

We illustrate the intervention explanation for T-OBJ sentences in LIS by repeating (14)–(15) in the sentences in (20) and (21) below and by underlining the context-shifting operator and the variable in object position and marking in bold the intervener:

(20) IX$_1$ FRIEND$_i$ DISCUSS IX$_3$ TELL IX$_1$ [OP GIRLFRIEND **IX$_{1(poss)}$** WANT MARRY IX$_1$]
'Talking with a friend he told me: My girlfriend wants to marry me.'

(21) OFFICE INSIDE COLLEAGUE$_i$ TELL IX$_1$ [OP TOMORROW SECRETARY$_i$ **IX$_i$** FOLDER$_i$GIVE$_1$]
'In the office a colleague told me: Tomorrow the secretary will give me a folder.'

This picture is also consistent with what we know about intervention effects in general, since they typically affect accuracy in sentence-to-picture matching tasks only with special populations, while they emerge only with more fine-grained measures, i.e. reaction times, in the general population.

Let us summarize: we propose that a pronominal index, which sits in subject position in many of the T-OBJ sentences, structurally intervenes between the context-shifting operator and the indexical to be shifted. Note that this explanation is consistent with the pattern observed in LIS RS T-SUBJ sentences: in eight out of sixteen, in addition to the pronoun to be shifted in subject position there is a pointing sign in object position. Mean accuracy for sentences with a pointing sign in object position was 0.73 (SD = 0.27) while accuracy for the other sentences was 0.64 (SD = 0.29). If the degradation is due to a structural intervention effect, as we proposed, this pattern is not surprising since the pointing sign in object position does not c-command the pronoun in subject position which must be shifted by the operator.

Two issues remain to be explained. First, why is the opposite pattern observed in LIS sentences with noRS, in which object dependencies appear to be *easier*? Second, what explains that no intervention effect of this kind is found in LSF?

Starting from the first question, we think that the better results in T-OBJ sentences compared to T-SUBJ sentences in the noRS condition is just the other side of the coin of the intervention effect that we observe in RS sentences: in order to correctly identify the picture associated to the noRS sentence, a participant must of course exclude the RS interpretation. But we just saw that associating the RS interpretation to T-OBJ sentences is challenging for LIS participants, therefore it is only expected that they are facilitated when the task requires excluding the interpretation that is difficult for them to grasp.

Moving to LSF, this language, as we mentioned, does not display any subject-object asymmetry. Given the prominence that our explanation gives to the presence

**Fig. 14** Pronouns in subject position (left) and object position (right) in LIS RS sentences

**Fig. 15** Pronouns in subject position (left) and object position (right) in LSF RS sentences

of a second pointing sign in LIS, we double checked the experimental stimuli in LSF and what emerges is that a pointing sign is present in the subject position in only one of T-OBJ sentences. However, a possessive pronoun is present in the subject NP in four sentences out of 12 (more specifically in sentences 2, 6, 7, 10 and 11). Therefore, prima facie LIS and LSF are not that different: an intervener occurs in some T-OBJ sentences in both languages. So, why are they differently affected? Remember that we are assuming a general account (motivated by intervention effects in *wh*-dependencies) according to which the intervention is modulated by featural similarity between the intervener and the bound variable (cf. (18–21) above). With this in mind, let us have a closer look at the features endowment of the relevant items in the two languages. In LIS, the pointing sign in subject position and the pronoun to be shifted in object position are both realized as a pointing index sign as shown in Fig. 14 (although the pointing sign might be incorporated when the verb is an agreeing verb).

In LSF, on the other hand, the potential intervener and the expression to be shifted have two very different realizations. The possessive in subject position is a specialized K-handshape sign, while the object position is filled by a sign that we gloss AUX-PERSON, following the convention used for a similar sign in LSC. The two signs are shown in Fig. 15.

We conjecture that the intervener is sufficiently dissimilar in LSF from the to-be-shifted category in object position not to create any intervention effect. This is so because of two reasons: first, they display different morpho-phonological properties (i.e. different handshapes); second, they belong to two different syntactic categories, namely the element in subject position is a possessive determiner, while the element in object position (i.e. AUX-PERSON) is an agreement auxiliary. Although no systematic description of this sign is available for LSF, the sign AUX-PERSON shares important properties with the correspondent sign in LSC. Both in LSC and in LSF,

this sign is derived from the lexical noun PERSON, it marks spatial agreement with first- and second-person arguments, and is normally used with plain verbs. All these shared properties support the extension of the analysis as an agreement auxiliary proposed by Quer and Frigola (2006) for AUX-PERSON in LSC to the correspondent sign AUX-PERSON in LSF.

All in all, we think that the intervention account has the capacity to explain the intricate pattern described. Under this view the subject advantage observed with RS in LIS becomes an indirect argument in favor of the view that RS requires a context-shifting operator and that this operator is represented in syntax. On the other hand, it seems to us that no obvious explanation for the intervention pattern is available by adopting the demonstration analysis.[17] Nevertheless, our proposal could be further investigated in future research with ad hoc materials, in LIS and LSF and in other sign languages.

Before turning to the effects of age of exposure, some words are needed to comment on the C-POSS items, where no effect of RS vs. noRS was observed in any of the languages investigated. Remember that C-POSS items contained a possessive first-person indexical modifying an NP in a simple small clause with no overt verb. It is possible that this structural simplicity makes the complexity of the shifting operation in the RS condition undetectable with simple behavioral data like the ones we are discussing here. The scarcity of data available on these items in our data set does not allow to go beyond this guess for the time being.

### 5.3 Effects of age of exposure in LIS and LSF

One of the goals of the present work was to analyze age of exposure effects on the comprehension of sentences reporting utterances. To do so, we compared the performance of native, early and late signers, three groups differing in age of first language exposure. As is evident by looking at the various box-plots reported in the results section, overall performance was variable across subjects. One reason for this variability could be the wide age range of our participants, a factor which is important, as confirmed by the fact that overall performance decreased as age increased. Nevertheless, we found clear group effects in all languages, even if with different nuances.

In LIS, we found group effects in most types of stimuli: native signers outperformed early and late signers in T-OBJ and T-SUBJ sentences with RS and in sentences without RS; in C-POSS sentences they outperformed early signers, but not late signers (however, notice that the performance of late signers on C-POSS sentences was extremely variable). Considering that the three groups of participants did not differ as for their level of education or in the results of the cognitive not-linguistic Odd

[17] A NLLT reviewer points out that it should be possible to test if a similar intervention effect emerges for clear cases of quotation and suggests the following paradigm for English:

(i) My friend was all, "I want to marry my girlfriend." (T-Subj, intervener)
(ii) My friend was all, "My girlfriend wants to marry me." (T-Obj, intervener)
(iii) My friend was all, "I want to marry Jenna." (T-Subj, no intervener)
(iv) My friend was all, "Jenna wants to marry me." (T-Obj, no intervener)

This is indeed an interesting proposal, but it goes beyond the scope of this paper.

One Out task, what we are observing here can be interpreted as the impact of late exposure on the comprehension of subordinate clauses of various degree of complexity.

In LSF, native signers outperformed early signers in all types of sentences with RS and in T-SUBJ and T-OBJ sentences without RS. Moreover, native signers outperformed late signers in all sentences with RS. Interestingly, in T-SUBJ and T-OBJ sentences in the RS condition the difference between early and late signers was not significant, whereas in sentences without RS, late signers outperformed early signers. The overall better performance of native signers can also be interpreted as evidence that delayed exposure to language has an impact on adults' syntactic competence. The performance of late signers, however, needs some further explanation. By considering T-SUBJ and T-OBJ sentences, one might hypothesize that the portion of late signers performing worse in RS preferred by default the no RS condition (see Fig. 8, accuracy of late signers is much more variable in sentences with RS compared to sentences without RS). This might be the reason why late signers outperformed early signers in T-SUBJ and T-OBJ sentences without RS, and the reason why the difference between late and native signers was not significant. As for C-POSS, the group difference was visible only in sentences with RS, and a possible explanation may lie in the fact that in these sentences accuracy of native signers themselves was extremely variable.

A question that we have not dealt with yet is whether the lower performance by non-native signers is due to a competence gap (non-native signers have developed a different grammar) or to a performance gap (the resources necessary for computation are scarcer in non-native signers). The question is not easily settled but we can advance some hypotheses. Data like the ones in Table 10 show that the intervention effect is modulated by AoE. In the acquisition literature, the fact that the intervention effect in object relatives and object *wh*-questions disappears with age in simple picture matching tasks (and remain visible only with subtle on-line measures), has been interpreted in terms of lower computational resources in young children. In principle, a similar explanation might be adopted here. Maybe using a first language acquired with a delay involves a bigger effort and this emerges in complex tasks.

We also proposed that a co-factor determining the particularly low performance of LSC non-signers is the fact that in LSC RS stimuli NMMs were relatively subtle and might have escaped non-native signers. This as well goes in the direction of a performance account. Having said that, we want to stress that we do not think that adopting a performance account exempts the researcher from doing a fine-grained linguistic analysis. On the contrary, only the latter analysis allows to identify those aspects of the derivation that are more challenging and require more computational resources, leading to a difference between populations.

All these results seem to add to an existing literature concerning other linguistic properties that shows that delayed exposure to language has effects that can be observed even decades after childhood and are likely to be lifelong.

A NLLT reviewer points out that in principle there is a different way of tackling the pattern we just summarized, namely interpreting the difference between the three groups as a difference between L1 acquisition (native signers) and L2 acquisition (the other groups, especially late signers). This different interpretation cannot be entirely excluded, as in the SIGN-HUB battery we did not include tests to assess participants'

reading/writing competence in the language spoken in their country. However, in the countries where our research took place, the late arrivals to sign language mostly come from two situations: during childhood when spoken language acquisition did not work and hearing families or the school opt for sign language as a 'rescue strategy,' or in adult life when the non-signing deaf person may decide to approach the Deaf community to build a Deaf identity. The latter situation was by design underrepresented among our participants being AoE not higher than 15 years, therefore the vast majority of our non-native participants falls in the first categorization. So, especially considering early signers, we are confident that the sign language was not learned *on a solid L2* because there was no (solid) spoken L1 to begin with. Then, considering that no differences emerged between early and late signers, we favor a line of discussion that does not consider potential differences between L1 and L2 acquisition. Having said that, we acknowledge that the interpretation proposed by the reviewer cannot be entirely excluded.

Given the importance of attitude (and action) role shift in everyday communication through sign language, the societal and educational relevance of our findings should not be underestimated, confirming one more time that no one should have a delayed exposure to language.

## 6 Conclusions and future directions

The first aim of this paper was to contribute psycholinguistic behavioral data to the theoretical debate about the analysis of the phenomenon of RS. According to our reasoning, if RS involves a context-shifting operator this operator might be sensitive to the structural constraints that syntactic operators are subject to. If this is the case, then the counterpart of the subject advantage which is normally found in A-bar dependencies should emerge in RS sentences.

We built a sentence-to-picture matching test aiming at measuring the comprehension of indexical first-person pronouns in various syntactic contexts under RS and without RS. This test was administered to approximately 120 signers in three sign languages: LIS, LSF and LSC. We did find a subject advantage in LIS, where a first-person pronoun was more difficult to interpret as shifted when in object position than when in subject position. As this pattern was not observed in LSF (LSC data were not considered for this theoretical discussion as the performance of all groups, native signers included, was very poor) we offered an explanation in terms of intervention and featural similarity. In LIS RS object sentences, the subject and the object pronouns display the same morpho-phonological features and belong to the same category (they are both pronominal indexes), while in LSF they display different morpho-phonological features and belong to a different category. To the extent that our analysis is correct, it supports the context shifting operator analysis over the demonstration analysis.

We stress that our argument in favor of the presence of a context-shift operator based on intervention effects is based on (and aims at explaining) attitude RS structures introduced by verbs of saying. Whether the context-shift analysis should be extended to action RS structures is something that we leave to future research.

A second general goal of our work was to contribute to assessing the impact of late language exposure on adults' competence by comparing RS comprehension across three groups of Deaf signers with different ages of first exposure to fully accessible language. In the three language groups, we found that native signers outperformed early and late signers in most or all conditions, thus confirming that delayed language exposure has a lasting impact on adults' comprehension of subordinate clauses of various degrees of complexity.

Last but not least, the present study is part of a larger project which aims at developing clinical tests for language assessment. Therefore, this test was also a pilot towards an applied goal, that of turning an experimental tool into a diagnostic test within a clinical battery. The test as used in the present research turned out to be too complex and long for the clinical use. However, some of the items that we developed (especially copular sentences with a possessive pronoun) could be included as complex items in a clinical battery aiming at assessing grammatical comprehension in general. Importantly, such a battery should have normative data considering not only chronological age, but also age of first exposure to language.

## Appendix 1: Biographical characteristics of the Italian participants

| N° Part | Gender | Age | Level of education | Age of first exposure to LIS | Cognitive task z-score |
|---|---|---|---|---|---|
| 01 | F | 43 | high school | 0 | 0.79 |
| 02 | M | 62 | high school | 4.5 | 0.79 |
| 03 | M | 48 | high school | 5 | −0.79 |
| 04 | M | 44 | high school | 0 | 0.79 |
| 05 | M | 65 | middle school | 7 | −0.79 |
| 06 | M | 42 | university | 0 | −0.79 |
| 07 | M | 59 | middle school | 7 | 0.79 |
| 08 | M | 36 | high school | 3 | −0.79 |
| 09 | M | 51 | middle school | 7 | 0.00 |
| 10 | M | 61 | high school | 3 | 0.79 |
| 11 | M | 56 | middle school | 5 | −1.58 |
| 12 | F | 43 | middle school | 0 | 0.79 |
| 13 | M | 41 | middle school | 3 | −0.79 |
| 14 | M | 40 | high school | 0 | −2.37 |
| 15 | F | 46 | high school | 3 | 0.79 |
| 16 | F | 42 | high school | 5 | 0.79 |
| 17 | F | 39 | university | 5 | 0.00 |
| 18 | F | 43 | high school | 0 | 0.79 |
| 19 | M | 39 | university | 0 | 0.00 |
| 20 | F | 57 | high school | 3 | −1.58 |
| 21 | M | 57 | high school | 3 | 0.79 |
| 22 | M | 39 | university | 7 | 0.00 |
| 23 | F | 40 | university | 0 | 0.79 |

| N° Part | Gender | Age | Level of education | Age of first exposure to LIS | Cognitive task z-score |
|---|---|---|---|---|---|
| 24 | F | 39 | high school | 3 | −0.79 |
| 25 | M | 38 | high school | 0 | 0.79 |
| 26 | F | 45 | high school | 0 | −3.94 |
| 27 | F | 30 | high school | 0 | 0.00 |
| 28 | F | 46 | high school | 0 | 0.00 |
| 29 | F | 41 | high school | 0 | 0.79 |
| 30 | F | 45 | high school | 15 | 0.00 |
| 31 | F | 60 | middle school | 0 | 0.00 |
| 32 | M | 45 | high school | 0 | 0.79 |
| 33 | F | 40 | high school | 13.5 | 0.79 |
| 34 | M | 62 | high school | 7.5 | 0.00 |
| 35 | M | 53 | middle school | 3 | 0.00 |
| 36 | M | 45 | high school | 10 | 0.79 |
| 37 | F | 45 | high school | 0 | −0.79 |
| 38 | F | 59 | middle school | 6 | 0.00 |
| 39 | F | 46 | high school | 10 | 0.00 |
| 40 | F | 34 | high school | 2 | −1.58 |
| 41 | M | 42 | high school | 5 | 0.79 |
| 42 | M | 42 | high school | 9 | 0.79 |
| 43 | M | 51 | high school | 13 | 0.79 |

## Appendix 2: Biographical characteristics of the French participants

| N° Part | Gender | Age | Level of education | Age of first exposure to LSF | Cognitive task z-score |
|---|---|---|---|---|---|
| 01 | M | 28 | university | 7 | 0.37 |
| 02 | M | 54 | high school | 0 | 1.28 |
| 03 | F | 30 | university | 1 | 0.37 |
| 04 | M | 36 | high school | 3 | 0.37 |
| 05 | F | 40 | university | 6 | −0.54 |
| 06 | M | 50 | high school | 0 | 0.37 |
| 07 | F | 27 | university | 2 | 0.37 |
| 08 | F | 38 | university | 0 | −0.54 |
| 09 | F | 31 | university | 6 | −1.44 |
| 10 | M | 40 | high school | 6 | −0.54 |
| 11 | F | 49 | high school | 0 | −0.54 |
| 12 | F | 43 | university | 0 | −1.44 |
| 13 | M | 35 | university | 0 | 0.37 |
| 14 | F | 39 | high school | 4 | −0.54 |
| 15 | F | 40 | university | 1.5 | −0.54 |
| 16 | F | 40 | high school | 0 | 0.37 |
| 17 | F | 35 | high school | 6 | 0.37 |
| 18 | M | 49 | high school | 0 | 0.37 |
| 19 | M | 25 | high school | 0 | 0.37 |
| 20 | M | 40 | high school | 14 | 1.28 |
| 21 | M | 44 | university | 0 | −1.44 |
| 22 | F | 30 | university | 5.5 | −1.44 |
| 23 | F | 39 | university | 3 | 1.28 |
| 24 | M | 32 | university | 0 | 0.37 |
| 25 | M | 38 | university | 0 | −1.44 |

| N° Part | Gender | Age | Level of education | Age of first exposure to LSF | Cognitive task z-score |
|---|---|---|---|---|---|
| 26 | F | 26 | university | 5.5 | 0.37 |
| 27 | F | 26 | university | 0 | 0.37 |
| 28 | M | 47 | university | 8 | 1.28 |
| 29 | F | 48 | university | 13.5 | −1.44 |
| 30 | F | 46 | high school | 4 | −0.54 |
| 31 | M | 27 | university | 3 | 0.37 |
| 32 | M | 29 | university | 2.5 | 1.28 |
| 33 | F | 36 | high school | 11.5 | 0.37 |
| 34 | M | 47 | high school | 5.5 | 1.28 |
| 35 | F | 35 | university | 4.5 | 1.28 |
| 36 | M | 25 | university | 0 | −1.44 |
| 37 | M | 30 | high school | 2.5 | 1.28 |
| 38 | F | 54 | high school | 7 | −0.54 |
| 39 | M | 19 | high school | 10 | −0.54 |
| 40 | F | 44 | high school | 12 | 0.37 |
| 41 | F | 24 | university | 4 | −2.35 |
| 42 | F | 23 | university | 14 | 1.28 |
| 43 | M | 72 | university | 9 | −1.44 |

## Appendix 3: Biographical characteristics of the Catalan participants

| N° Part | Gender | Age | Level of education | Age of first exposure to LSC | Cognitive task z-score |
|---|---|---|---|---|---|
| 01 | F | 45 | middle school | 0 | −0.68 |
| 02 | M | 62 | primary school | 0 | −0.68 |
| 03 | F | 54 | primary school | 0 | 0.29 |
| 04 | M | 38 | middle school | 0 | −0.19 |
| 05 | M | 26 | middle school | 0 | −0.68 |
| 06 | F | 51 | primary school | 0 | 0.77 |
| 07 | M | 55 | middle school | 0 | −0.68 |
| 08 | M | 51 | middle school | 0 | 0.29 |
| 09 | F | 30 | high school | 0 | 0.29 |
| 10 | F | 27 | high school | 0 | 0.29 |
| 11 | M | 69 | primary school | 0 | −5.51 |
| 12 | M | 31 | university | 0 | 0.29 |
| 13 | M | 23 | middle school | 3 | −0.19 |
| 14 | F | 26 | university | 0 | 0.29 |
| 15 | F | 51 | primary school | 0 | 0.77 |
| 16 | M | 41 | high school | 3 | 0.29 |
| 17 | F | 54 | primary school | 5 | −0.19 |
| 18 | M | 52 | high school | 3 | −0.19 |
| 19 | F | 63 | middle school | 3 | 0.77 |
| 20 | F | 49 | middle school | 3 | 0.29 |
| 21 | F | 45 | middle school | 3 | 0.77 |
| 22 | F | 55 | middle school | 4 | 0.29 |
| 23 | M | 62 | primary school | 4 | −0.19 |
| 24 | F | 56 | middle school | 3 | 0.29 |
| 25 | M | 51 | middle school | 3 | 0.29 |
| 26 | M | 46 | middle school | 3 | 0.29 |
| 27 | F | 63 | primary school | 6 | 0.29 |
| 28 | F | 59 | middle school | 6 | 0.29 |
| 29 | F | 64 | high school | 4 | 0.29 |

| N° Part | Gender | Age | Level of education | Age of first exposure to LSC | Cognitive task z-score |
|---|---|---|---|---|---|
| 30 | F | 62 | primary school | 4 | 0.29 |
| 31 | F | 48 | middle school | 4 | 0.29 |
| 32 | M | 45 | middle school | 12 | −0.19 |
| 33 | F | 48 | high school | 10 | 0.77 |
| 34 | M | 52 | primary school | 12 | −0.68 |
| 35 | F | 41 | university | 7 | 0.29 |
| 36 | M | 54 | middle school | 15 | 0.77 |
| 37 | M | 52 | middle school | 9 | 0.29 |
| 38 | M | 62 | high school | 14 | 0.29 |
| 39 | M | 43 | high school | 13 | 0.29 |
| 40 | M | 59 | Middle school | 8 | 0.29 |

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**Data Availability** Raw video materials and data are available on an OSF repository (https://osf.io/emp6g/). The role shift comprehension tests presented in this paper are part of the SIGN-HUB assessment tests (https://www.sign-hub.eu/assessment/welcome-page-assessment) and are named respectively SYNTRSLSF – Role shift comprehension task in LSF (Aristodemo et al. 2019), SYNTRSLIS – Role shift comprehension task in LIS. (Sala et al. 2019), SYNTRSLSC – Role shift comprehension task in LSC (Zorzi et al. 2019a).

**Code Availability** Code to perform the analysis is available on an OSF repository (https://osf.io/emp6g/).

## Declarations

**Conflicts of interest/Competing interests** The authors declare that they have no conflict of interest.

**Ethics approval** The study was approved by the Ethical Committee of each participating research group (France: CERES, IRB n° 20163400001072; Italy: Milan Bicocca Ethical Committee, prot. n° 0019845/16; Spain: Parc de Salut MAR – Clinical Research Ethics Committee, prot. n° 2016/6715/I).

**Consent to participate** All participants signed a consent form before participation.

**Consent for publication** Not applicable.



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## Authors and Affiliations

**Valentina Aristodemo[1] · Beatrice Giustolisi[2] · Giorgia Zorzi[3] · Doriane Gras[1] · Charlotte Hauser[1] · Rita Sala[2,4] · Jordina Sánchez Amat[3] · Caterina Donati[1] · Carlo Cecchetto[2,4]**

✉ B. Giustolisi
beatrice.giustolisi@unimib.it

1 Université Paris Cité & CNRS – UMR 7110 Laboratoire Linguistique Formelle, Paris, France

2 Department of Psychology, University of Milan – Bicocca, Piazza dell'Ateneo Nuovo, 20126, Milan, Italy

3 Universitat Pompeu Fabra, Barcelona, Spain

4 Université de Paris 8 & CNRS–UMR 7023 Structures Formelles du Langage, Paris, France