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# On the reliability of the notion of native signer and its risks

**Keywords: sign languages, native signer, early and late signers, effect of age of exposure.**

## Abstract

Who is a native signer? Since around 95% of deaf infants are born in a hearing family, deaf signers have access to a sign language at various moments of their life, and not only from birth, and the linguistic input they are exposed to is not always a fully-fledged natural sign language. In this situation, is it the notion of native signer as someone exposed to language from birth of any use? We report the results of the first large scale cross-linguistic investigation on the effects of age of exposure to sign language. This research involved about 45 Deaf adult signers in each of three sign languages (LIS, LSC, LSF). Across the three languages, participants were divided into three groups: those exposed from birth, those between 1 and 5 years of age, and those exposed between 6 to 15 years of age. We report the results of a battery of tests designed for each language investigating various aspects of lexical and morphosyntactic competence. In particular, these tests focused, beside lexical comprehension, both on those morphosyntactic phenomena that are known from the spoken language literature to be good detectors of language impairment or delay (i.e., *wh*- interrogative and relative clauses) and on morphosyntactic phenomena that are sign language specific (i.e., role shift and directional verbs). Our results showed a clear effect of being native in the morphosyntactic competence, with significant differences across language and tests between signers exposed to sign language from birth and those exposed in the first years of life. This confirms the life-long importance of language exposure from birth and the reliability of the notion of nativeness, at least for syntax. On the other hand, while in most domains the differences observed between populations might be differences in performance, for some specific constructions signers belonging to the three groups may have different grammars. This latter finding challenges the generalized use of native signer's grammar as the baseline for language description and language assessment.

## 1. Introduction

The notion of 'native' user of a language has become controversial for various reasons. For spoken languages, the challenge comes from bilingualism and multilingualism (Sorace, 2021 for an overview), while for sign languages the controversy is due to the unique sociolinguistic situation that characterizes the population of Deaf signers.[1] The linguistic profiles attested among deaf people are very diverse, and native signers, defined as deaf individuals who were born into a Deaf signing family, are only a small minority. This led many scholars to challenge the importance of this notion as a reliable criterion for language description and assessment, at least as far as sign languages are concerned. The question is whether 'nativeneness' is indeed different from early exposure: in other words, whether what really matters is being early exposed to a sign language, or whether there is a special status associated to being native, even with respect to early learners.

In this paper we will first discuss the controversial status of 'native signers' with respect to the global population of Deaf signers (§2), underlying that most experimental studies have not been using consistent criteria to contrast natives from signers who were not exposed to a sign language from birth (§2.2). With the goal of contributing with experimental methods to the debate of whether natives are indeed different from non-natives, in section 3 we will present the tests developed within the Horizon

[1]Following standard practice, in this paper we use the word "deaf" with low case "d" to refer to the audiological condition of a deaf individual. The word "Deaf" with capital "D", instead, will be used to refer to the deaf members of a community who use a sign language, with its own cultural identity.

2020 project SIGN-HUB ("The Sign Hub: preserving, researching and fostering the linguistic, historical and cultural heritage of European Deaf signing communities with an integral resource") describing the criteria that were used to select the groups of native, early and late signers (§3.1), and the tests themselves (§3.2), and providing a summary of the results (§3.3). In section 4, we will then discuss the results presented in the previous section and support the claim that natives have indeed a different performance in comparison to signers who were exposed later to sign language, even early in life. At the same time, we will challenge the reliability of native signers' grammar as the baseline to be used for sign language investigation and assessment (§4.2).[2]

## 2. The controversial notion of 'native signer'

The population of deaf pre-lingual adult signers is extremely heterogeneous, as it is characterized by people with very different linguistic backgrounds. This is due to the sociolinguistic situation that characterizes deaf people and Deaf communities. The general estimation is that only 5 to 10% of deaf babies have deaf signing parents, and even less have deaf signing grandparents (Newport, 1988; Neidle, et al., 2000; Mitchell & Karchmer, 2004) and therefore only a small part of the deaf population is exposed to sign language from birth. This percentage, however small, has been calculated on the deaf population of the United States, but it has been questioned as an overestimation for the deaf population in Australia (Johnston, 2006) and Europe (Costello et al., 2008). Costello et al. (2008) looked at the deaf signers in the Basque Country, in the north of Spain, underlining that the number of deaf people born into Deaf families is extremely low and it hardly reaches 5%. This aspect needs to be taken into consideration especially when looking at deaf populations in smaller communities.

### 2.1. How deaf children get exposed to language

If we consider the general definition of native signers as 'Deaf people who grew up with Deaf signing parents and who identify with the Deaf community' (Neidle et al., 2000), it is clear that it refers to a very small part of the deaf population. In addition to this, it is important to remark that some deaf parents might have been themselves exposed to sign language at a late point in life and therefore might provide a language input to the child that cannot be strictly compared to the one of a native (Lillo-Martin, 2021). Even if it has been shown that deaf children exposed to a poorer sign language from birth reach a better performance than their parents and get close to their native peers, they are still not native-like (Singleton & Newport, 2004). Deaf children exposed to a native input might thus be exceedingly rare.

As for the rest of the deaf population, more than 90%, is constituted of deaf children born in hearing families, and therefore for the most part they are not exposed to sign language from birth. There are several factors that prevent the deaf population from being exposed to an early and adequate sign language input that would allow an early and natural language acquisition. The main reasons are the age of diagnosis, although it has recently drastically decreased due to newborn hearing screening (Joint Committee on Infant Hearing 2019), the different degrees of deafness and the use of technologies such as cochlear implants or hearing aids, together with the type of language intervention adopted by the parents: they might opt for exposure to spoken language via amplification through hearing aids or cochlear implants, or rather for exposure to both spoken and sign languages or for exposure to sign language only. In many cases parents are advised by doctors and educators to adopt an oralist approach

[2] This paper is intended as a summary of results stemming from the SIGN-HUB research group experimental work involving Deaf adults belonging to three sign language communities: LIS (Italian Sign Language), LSC (Catalan Sign Language), LSF (French Sign Language). Since most of the relevant articles whose results we summarize in this paper are not published yet, the details about statistical analyses and exact figures will be reported only for the study on relative clauses, published in Hauser et al. (2021a).

supporting the use of technologies meant to facilitate the learning of spoken languages, denying sign input (Lillo-Martin, 2021). Even with early intervention through hearing aids or cochlear implants, though, language access is delayed if not provided through a fully accessible natural language, which in the case of deaf children is in the visual-gestural modality (Hall et al., 2019, Humphries et al., 2016, a.o.). In a very small percentage of cases, hearing parents decide to learn sign language and expose their child to it (cf. Chen-Pichler & Lillo-Martin, 2018), hence still delaying giving a sign language input while they go through the process of learning the language. Eventually, the input they provide cannot be compared to the one of a deaf native signer (Lillo-Martin, 2021), even though it is provided early in life. Only a minority of deaf children born in hearing families is then exposed to sign language in their parental home shortly after diagnosis. In most cases, it is only at school, often after the failure of spoken language learning, that deaf children get exposed to sign language.

A delayed exposure to sign language leads to a delay in the development of language, and even abnormal neurological mappings of language (Mayberry, 2010; Mayberry & Kluender, 2018; Woll, 2018). Moreover, it has sociolinguistic consequences in relation to how deaf people not exposed to sign language from birth relate to the Deaf community. For German Sign Language (DGS), Jaeger (2009) distinguishes between a 'native' and an 'authentic' signer. Many participants to her study who were non-native reported that they identify themselves as 'authentic signers', specifying that such status can be reached either by being born into the Deaf community ('Deaf aristocracy'), or via intentional change ('Deaf meritocracy'), as was the case for most of them. This perspective on non-native signers as being native-like from an identity perspective relates to the conceptualization of non-natives as 'New Signers', a concept adapted from that of 'New Speaker'. The term 'New Speaker' was introduced to indicate users who acquire a minority language later in life and outside the parental home (O'Rourke et al., 2015), especially in the context of language revitalization (Jaffe, 2015). It has been recently extended to deaf non-native signers since they share the characteristics of acquiring language after childhood and outside the parental home (Jaeger, 2009) and because of the status of sign languages as minority languages (Tupi, 2019; Bauman & Murray, 2017). The New Signer model gives a new perspective to the 'native speaker' ideology and shows that it is important to disentangle sociological and psycholinguistic factors when it comes to identify the profile of a native signer.

Concretely, studying a sign language by only relying on native signers might end up as an impossible task. The alternative that has been adopted in the literature is to work with consultants that fulfill several criteria that make them as close as possible to the standard definition of native signers (Quer & Steinbach, 2019). As reported by Costello et al. (2008), many research groups tend to select participants, especially for neurolinguistic studies, who are (at least) second generation deaf-of-deaf signers. On the other hand, Mathur & Rathmann (2006) consider three main criteria: (i) exposure to sign language by the age of three; (ii) ability to give grammaticality judgment with ease; (iii) daily contact with a sign language in the Deaf community for more than 10 years. In experimental data assessing language acquisition and the impact of age of exposure (AoE) on language competence, native signers tend to be strictly identified with individuals who have been exposed to sign language from birth from Deaf signing parents. Oftentimes, though, a limit of three years of age is established in order to consider someone as native (Mayberry, 1993; Freel et al., 2011).

It is clear that determining the exact criteria that define an individual as having native competence is particularly crucial when the aim is to assess the consequences that a delay to language exposure can cause later or earlier in life. In the following section, we provide an overview of the profiles of deaf signers that have been studied in this type of studies. In many cases, their goal is to determine whether native signers, even if they constitute a minority, can be distinguished from signers who have been exposed to sign language even quite early in life, as far as language development is concerned.

### 2.2. Age of exposure to sign language

Early exposure to language is crucial to language acquisition (Mayberry et al., 2002) and this has been documented for sign languages since the '90s, with studies showing that non-native signers differ from native signers in several morpho-syntactic tasks. Emmorey et al. (1995), in a study on sign recognition within a sentence containing errors in verb agreement showed that only native signers were sensitive to agreement errors, while late learners were not. The relevant group of late learners were exposed to American Sign Language (ASL) between 4 and 20 years of age. In a second experiment involving sign recognition in a sentence containing errors in verb agreement or aspect and offline grammaticality judgements, non-natives were distinguished into early and late signers, with AoE range of 2-7 years and 10-20 years, respectively. The results of the first experiment were confirmed, with natives outperforming non-natives regardless of their AoE group. In other studies on ASL, though, the AoE effect was gradient, showing a continuum among the groups: as AoE increased, the performance of signers decreased. This is the case of a study on ASL sentence processing measured by recall of long and complex sentences. In this study, Mayberry (1993) included three groups of pre-lingual deaf signers with AoE ranging from i) 0-3 years of age, ii) 5-8 years, and iii) 9-13 years (and a fourth group of post-lingual deaf signers who were exposed to ASL between 8 and 15 years of age and lost their hearing between 8 and 12 years of age). The performance of the pre-lingual deaf signers decreased as AoE increased. A similar result was obtained using a grammaticality judgement task on sentences of various types, independently from the syntactic structure investigated (Boudreault & Mayberry, 2006). In the same task, reproduced by Cormier et al. (2012) in British Sign Language (BSL), accuracy in the grammatical judgement task decreased as AoE increased for Deaf early signers, while no decreasing related to AoE was found among Deaf late signers. However, if we compare the AoE of late learners in the two versions of the study, we observe that while in the ASL experiment late learners were exposed to ASL between 8 and 13 years, in the BSL experiment late learners were exposed to BSL between 9 and 18 years. More importantly, late ASL signers were described as L1 signers, whereas Cormier et al. (2012) suggest that their group of late signers was composed of L2 signers, with English as L1. The upward trend for the oldest AoE was then attributed to having acquired another language from birth.

Effects of AoE have also been reported for phonological processes and lexical access. Emmorey & Corina (1990) reported that natives are faster than late learners (mean AoE = 11 years) in recognizing signs in a gating task, and found a categorical difference between the two groups. Similar results were reported for ASL by Marford & Carlson (2011) on a sign recognition with gating task.[3] In an immediate recall of digit and of simple and complex sentences at normal and speeded rate, Mayberry & Eichen (1991) found that AoE in adults who were exposed to SL as children or adolescents had significant effects on performance at all levels of linguistic structure. The effect reported for the three groups of adult signers, natives, childhood learners (AoE = 5-8 years) and adolescent learners (AoE = 9-13 years), was again gradient and not categorical.

The characteristics of the various groups of signers participating in the experiments just presented are summarized in Table 1 below.

*Table 1. Summary of the AoE of participants across a selection of relevant studies on the impact of AoE.*

| **Language** | **Task** | **Participants** |
|---|---|---|

[3] In Marford & Carlson 2011, the range of AoE for native signers is not specified and it is only reported that "they all acquired ASL in the home prior to attending school". For this reason, details about the participants in this study are not further summarized in Table1.

| | | |
|---|---|---|
| **ASL** | Sign recognition with gating (Emmorey & Corina, 1990) | i) 8 Natives: AoE = birth, M age = 31<br>ii) 8 Late: M AoE = 11, M age = 32, M SLe= 21[4] |
| | Immediate recall of digit, simple sentences and complex sentences at normal and speeded rate (Mayberry & Eichen, 1991) | i) 16 Natives: AoE = from birth, M Age = 40 (30-60), M SLe= 40 (30-60)<br>ii) 20 Childhood learners: AoE = 5-8, M Age = 51 (29-64), M SLe = 44 (25-58)<br>iii) 13 Adolescent learners: AoE = 9-13, M Age = 53 (33-70), M SLe = 42 (21-59) |
| | Sign recognition in a sentence containing errors in verb agreement (Emmorey et al., 1995) | i) 11 Natives: AoE = birth, Age = 21-44<br>ii) 10 Late: AoE = 4-20 (M = 12), Age = 29-49 |
| | Sign recognition in a sentence containing errors in verb agreement or aspect and offline grammaticality judgements (Emmorey et al., 1995) | i) 10 Natives: AoE = birth, Age = 19-24<br>ii) 10 Early: AoE = 2-7 (M = 4), Age = 21-37<br>iii) 10 Late: AoE = 10-20 (M = 14), Age = 22-46 |
| | Sentence processing (Mayberry, 1993) | i) 9 AoE = 0-3 (M = birth), M Age = 51 (43-67 ), M SLe = 51 (43-67), born deaf<br>ii) 9 AoE = 5-8 (M = 7), M Age = 61 (37-71), M SLe = 51 (31-65), born deaf<br>iii) 9 AoE = 9-13 (M = 11), M Age = 60 (40-72), M SLe = 54 (28-61), born deaf<br>iv) 9 AoE = 8-15 (M = 11), M Age = 60 (38-72), M SLe = 50 (29-61), onset deafness: 8-12 (M = 9) |
| | Grammaticality judgement task on sentences (Boudreault and Mayberry, 2006) | i) 10 Natives: AoE = birth, M age = 24.2 (18-41), M SLe = 24.3 (18-41)<br>ii) 10 Early: AoE = 5-7 (M = 5.6), M Age = 43.2 (31-62), M SLe = 37.6 (14-47)<br>iii) 10 Late: AoE = 8-13 (M = 10.3), M Age = 43 (24-79), M SLe = 32.9 (13-71) |
| **BSL** | BSL version of Boudreault and Mayberry's task (Cormier et al., 2012) | i) 10 Natives: AoE = birth, M Age = 39.7 (20-57), M SLe= 39.7 (20-57)<br>ii) 11 Early: AoE = 2-8 (M = 4.4), M Age = 36.5 (19-54), M SLe = 32 (17-51)<br>iii) 9 Late: AoE = 9-18 (M = 12.8), M Age = 30.9 (20-43), M SLe = 18.1 (10-26) |

From Table 1, focusing on AoE, we can clearly see that there is a lot of variation across studies on the groups of signers investigated and how they are defined: in some cases, native signers are compared directly to late learners. In other cases, when three populations are indeed distinguished, the AoE range of the three groups varies a lot. It is possible to see variation in the definition of early and late signers even in the 'replication' of the same study (cf. Boudreault & Mayberry, 2006, and Cormier et al., 2012). Moreover, in Mayberry (1993) the category with the earliest exposure to ASL includes signers who were exposed before 3 years of age, without excluding natives from this sample.

[4] SLe refers to the years of 'sign language experience'.

Under these circumstances, it is thus very difficult to compare the results of the various studies. In particular, it is not clear whether the effect of AoE found in the literature so far is a simple effect of being early exposed to a sign language, or whether there is a special status associated to being exposed from birth even with respect to early learners.

With the aim at understanding whether natives differ categorically from non-natives, or whether what matters is simply early exposure to sign language for which we expect a gradient effect associated to different AoE groups, we developed within the SIGN-HUB project a number of morpho-syntactic and lexical comprehension tests on three different sign languages. These tests are language specific but were created adopting similar designs and, crucially, they were administrated to participants who were selected and divided into groups using the same criteria: native signers (AoE = 0), early learners (AoE = 1-5) and late learners (AoE = 6-15). The languages involved were Catalan Sign Language (LSC), French Sign Language (LSF) and Italian Sign Language (LIS). The SIGN-HUB project tests, in addition to providing data on the understanding of the effect of AoE in signers, also contribute to the comparative analysis of some specific linguistic phenomena.

In this section we discussed the reasons for the controversy surrounding the notion of 'native signer'. As we will see in section 3 below, the SIGN-HUB project aims at verifying whether natives should be distinguished from non-natives in their linguistic competence/performance. We shall see that by consistently using the same criteria to define natives, early and late learners in the various tests and in three sign languages, the project is able to provide robust conclusions on the existence of a categorical opposition between natives and non-natives.

## 3. Native, early and late signers in a large scale crosslinguistic investigation

As already mentioned, the SIGN-HUB project tests were specifically designed for three sign languages: Catalan Sign Language (LSC), French Sign Language (LSF), and Italian Sign Language (LIS). The tests aimed at assessing lexical and morphosyntactic competences in different populations of Deaf signers. They were developed to study complex structures that are characterized by long-distance dependencies and known to be good detectors of language impairment or delay (i.e., relative clauses and *wh*- questions), as in Friedman et al. (2009), and sign language modality specific constructions (i.e., role shift and expression of agreement through directional verbs). A secondary goal was to start developing clinical tests to assess language impairment in Deaf adults. With this purpose in mind, lexical tasks were mostly designed in order to investigate potential impairments at the lexical level, in the phonological system and in the semantic one, respectively, and only secondarily in order to verify whether AoE had an impact in the development of the lexicon.

For the three languages, an average of 45 deaf signers with different age of exposure to sign language were recruited. Across the three languages, participants were divided into three groups: those exposed from birth, those exposed between the age of 1 and 5 (included), and those exposed to sign language between 6 to 15 years of age.

The results were clear: Deaf signing adults who were exposed to sign language from birth outperformed the two other groups of signers in the comprehension of complex syntactic structures in their native language. No such difference emerged in the lexical tests.

In the following subsections, we describe the characteristics of the three groups of participants. We then present each test and the results obtained. We shall only discuss here those data that are directly relevant for the question under discussion, namely the impact of AoE, while we refer to the specifc papers for findings unrelated to the research question that is our focus in this paper.

### 3.1. The participants

For the three languages (LIS, LSC and LSF), participants were selected following three general inclusion criteria: i) onset of deafness no later than 3 years of age;[5] ii) first exposure to sign language no later than 15 years of age; iii) the target sign language as their preferred mean of communication. All participants had been exposed to sign language for at least 15 years, with the exception of two young LSF participants, who both had only 9 years of sign language experience.

To be able to create groups of participants with a similar language input and background, we asked them to fill in a questionnaire containing several personal questions including the age of first exposure to sign language, the possible deafness of their parents, whether their parents were signers, whether they went to a school for the deaf or had deaf school mates, and so on.[6] The collection of these metadata allowed us to distinguish three groups of participants: i) native, ii) early and iii) late signers. As already mentioned, native signers were individuals exposed to sign language from birth (AoE= 0), having deaf signing parents, and who therefore acquired SL in a familiar environment. Early learners were exposed to sign language between 1 and 5 years of age while late learners between 6 to 15 years of age. In both groups of non-natives, most participants were introduced to sign language in school, almost none had deaf parents, and very few had at least one parent knowing sign language. The following chart in Table 2 summarizes the characteristics of all participants that we considered for the first participant selection.

*Table 2. Summary of participants' characteristics per group and language.*

| **Group** | **SL** | **N.** | **AoE** | **Everyday use of SL** | **Deaf parent(s)** | **Signing parent(s)** | **Context of exposure to SL** | **Years of SL experience** |
|---|---|---|---|---|---|---|---|---|
| **NATIVE** | **LIS** | 16 | 0 | 16 | 16 | 16 | Family: 16 | 30-60 (M = 43) |
| | **LSC** | 14 | 0 | 13[7] | 14 | 14 | Family: 14 | 26-69 (M = 44) |
| | **LSF** | 14 | 0 | 13[8] | 13 | 13 | Family: 12 (1 NS) | 26-54 (M = 39) |
| **EARLY** | **LIS** | 15 | 2-5 yrs (M: 3,9) | 13 | 1 | 3 | Family: 4 School: 10 (1 NS) | 32-58 (M = 47) |
| | **LSC** | 16 | 3-5 yrs (M: 3.5) | 15 | 1 | 2 | Family: 3 School: 13 | 20-60 (M = 48) |
| | **LSF** | 15 | 1-5.5 yrs (M: 3.4) | 10 | none | 1 | Family: 3 School: 11 (1 NS) | 20-39 (M = 30) |

[5] Concerning the onset of deafness, participants self-reported that it was never later than 3 years old (LIS: M = 3.5 months, LSC: M = 5.6 months, LSF: M = 3.7 months).

[6] Questionnaires were written, but a signing person was present so participants who had doubts could ask for a translation.

[7] For LSC, 1 native signer, 1 early and 1 late declared to use LSC "often" instead of "everyday".

[8] For LSF, 1 native, 5 early and 3 late signers declared to use LSF "often" instead of "everyday".

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **LATE** | **LIS** | 13 | 6-15 yrs (M: 9.1) | 11 | none | 1 | Family: 2<br>School: 9<br>(2 NS) | 26-58 (M = 41) |
| | **LSC** | 12 | 6-15 yrs (M: 10.4) | 11 | 1 | 2 | School: 8<br>(4 NS) | 34-57 (M = 41) |
| | **LSF** | 14 | 6-14 yrs (M: 9.2) | 11 | 2 | 1 | Family: 1<br>School: 9<br>(4 NS) | 9-63 (M = 31) |

The questionnaires participants filled in were also used to collect more general personal information. Table 3 summarizes data about chronological age (inserted as a factor in the various analyses), gender, degree of deafness, and use of hearing aids, of the final pool of participants considered in our analyses. The questionnaire was meant also to collect information about participants' use of written language (either Italian, Catalan, Spanish or French). We asked them to self-rate whether they used written language every day, and if they read newspapers etc. However, the data we obtained were often not coherent and in any case not very fine-grained, and we could not use it as a factor in the analyses.

*Table 3. Summary of participants' general characteristics per group and language.*

| **Group** | **SL** | **N.** | **Age** | **Gender** | **Degree of deafness** | **Hearing aids** | **Education** |
|---|---|---|---|---|---|---|---|
| **NATIVE** | **LIS** | 16 | 30-60 (M = 43) | 10 female<br>6 male | 15 profound[9]<br>1 moderate | 6 hearing aids | Median = high school |
| | **LSC** | 14 | 26-69 (M = 44) | 7 female<br>7 male | 13 profound<br>1 moderate | None | Median= university education |
| | **LSF** | 14 | 26-54 (M = 39) | 6 female<br>8 male | 9 profound<br>5 severe | 7 hearing aids<br>1 cochlear implant | Median= middle school |
| **EARLY** | **LIS** | 15 | 34-62 (M = 48) | 7 female<br>9 male | 14 profound<br>1 severe | 5 hearing aids | Median = high school |
| | **LSC** | 16 | 23-64 (M = 51) | 10 female<br>6 male | 16 profound | None | Median= middle school |
| | **LSF** | 15 | 24-47 (M = 34) | 10 female<br>5 male | 13 profound<br>2 severe | 4 hearing aids<br>1 cochlear implant | Median= university education |
| **LATE** | **LIS** | 13 | 40-65 (M = 50) | 4 female<br>9 male | 10 profound<br>2 severe<br>1 moderate | 3 hearing aids<br>1 cochlear implant | Median = high school |
| | **LSC** | 12 | 41-63 (M = 52) | 5 female<br>7 male | 10 profound<br>2 severe | 5 hearing aids | Median= middle school |
| | **LSF** | 14 | 19-72 (M = 40) | 8 female<br>6 male | 12 profound<br>2 severe | 6 hearing aids<br>1 cochlear implant | Median= high school |

All participants were tested with the Odd One Out Cognitive Task (cf. Giustolisi & Friedmann, 2019, for LIS, Zorzi, Sánchez Amat & Friedmann, 2019, for LSC and Aristodemo & Friedmann, 2019,

[9] We considered as 'profound' a degree of deafness higher than 90 dB, as 'severe' a degree between 71 and 90 dB, and as "moderate" a degree of deafness between 41 and 70 dB.

for LSF), which was designed to detect potential cases of cognitive impairment. In this test, participants needed to find the intruder in a set of four pictures (see Figure 1 for an example). The Odd One Out Cognitive Task displayed 28 items preceded by two training items. For each participant, z-scores were calculated considering language group mean and standard deviations, Participants with z-scores lower than -2.5 were excluded from the study.



*Figure 1. Example of one item of the Odd One Out Cognitive Task.*

One native participant was excluded both from the LIS pool and for the LSC pool. The LIS participant had a z-score of -3.94 and the LSC one a z-score of -5.51. No participant was excluded from the LSF pool.

### 3.2. The tests

In this section we describe each comprehension test that was developed within the SIGN-HUB project for LIS, LSC and LSF, briefly going through their methods and results. The tests were computerized and built using a software specifically developed for the SIGN-HUB project. The input signs and sentences were discussed, selected, and recorded in collaboration with Deaf native signers who are experienced consultants for each language at the respective universities involved. It is important to underline that the language input that was tested corresponds to the one of native signers.

We first introduce the lexical tests and their results (§3.2.1), and then focus on the syntactic tests (§3.2.2). We start with the ones that target relative clauses and *wh*- questions (§3.2.2.1) and then present the SL specific ones on role shift and directional verbs (§3.2.2.2). We then provide a summary of the results of the syntactic tests (§3.2.3). We show that there is an effect of AoE group and that native signers can indeed be categorically distinguished from the other two groups, even though in the lexical tests the results are more nuanced.

#### 3.2.1. Lexical tests

For each sign language we developed two lexical comprehension tasks, one with phonological distractors and one with semantic distractors. These tests were created with the first goal of using them as clinical tools to assess language impairment in Deaf adults and only secondarily to verify the impact of AoE. Moreover, the tests have been constructed aiming at maximizing overlapping across sign languages and thus facilitate cross-linguistic comparison of the results.

Items were selected following three criteria: a) minimize regional variation; b) avoid 'extreme transparency'; c) representability with a picture. Proper names, classifiers and compounds were excluded. In order to minimize regional variation, the signs were selected in collaboration with Deaf SL experts with metalinguistic awareness related to lexical variation in the country of the SL assessed. As for the level of transparency and the representability with a picture, stimuli were controlled through validations administered to hearing non-signers from the same country of the sign language assessed. Pictures were validated through two tasks: naming agreement (see an image and write what it represents) and matching agreement (see a word and select the corresponding image among the ones selected

as target and distractors in the test). Pictures that were not identified by 75% of the participants were excluded. Complexity rating in a 1-4 scale was also administered to have a measure of the complexity of the images. To measure the transparency of signs, a transparency agreement validation test (see a sign and write what it means) and a matching agreement test (see the target sign and select the corresponding image among the ones selected as target and distractors in the test) were administered. These two validations were not used to discard any item, unless the sign was guessed by all hearing participants, but to establish a scale of transparency that can be integrated in the analysis when the tests will be used in a clinical setting.

Considering the lexical comprehension task with phonological distractors (cf. Zorzi et al., 2019f, h, d, for LIS, LSC and LSF, respectively), three tests including from 22 to 25 target signs has been constructed (see the Supplementary Material for details on the number of items and characteristics of the participants for each language). Each sign was presented with six pictures, one corresponding to the target, and five to phonological distractors, i.e., pictures representing signs that are formationally similar to the target. More precisely the distractors were three minimal pairs and two phonologically related distractors. No distractor belonged to the same semantic category of the target.

As for the lexical comprehension task with semantic distractors (cf. Zorzi et al., 2019g, i, e, for LIS, LSC and LSF, respectively), for each language the test included 18 target signs (see the Supplementary Material for details on the number of items and characteristics of the participants for each language). Each item was presented with eight pictures, one corresponding to the target, six to semantic distractors, i.e., pictures corresponding to signs that are close semantic competitors of the target, and one to a semantic distractor within the same semantic category, but also visually related to the target. For more details on the selection of the distractors and their characteristics, see Aristodemo et al. (2021b).

In both types of tasks, the participant watched a video with the target sign while six (tests with phonological distractors) or eight (tests with semantic distractors) pictures were displayed and had to click on the matching picture (see Figure 2). Each video could be watched only once.



*Figure 2. Example of one item of the Lexical comprehension task with phonological distractors in LSC (target sign: CROISSANT), on the left, and one item of the Lexical comprehension task with semantic distractors in LSC (target sign: CHOCOLATE), on the right.*

The results of these two lexical tests in the three languages did not show a clear impact of AoE, and all participants had a very good performance, but it is still possible to notice an overall tendency of native signers to perform better, especially compared to late learners. This tendency was not consistently found in the three languages[10].

[10] The tests have been run so far only with Deaf adults without language impairment and we are therefore aware of a possible ceiling effect due to the small number of items used.

Overall, in the lexical comprehension task with phonological distractors, in LIS, LSC, and LSF, AoE group did not significantly affected accuracy (Aristodemo et al., 2021b). Only in LSF, the performance of early signers was significantly different from that of late signers. In LIS and LSC there was an effect of chronological age. The population in these two languages is on average older than the LSF one, and we observed that performance decreased as chronological age increased.

In the lexical comprehension task with semantic distractors, in LIS, LSC, and LSF, AoE group again was not a significant predictor of accuracy (Aristodemo et al., 2021b).

The results of the lexical tests suggest that AoE does not play a major role on the comprehension of lexical elements. Biological age appears to be relevant for the comprehension task with phonological distractors, though. This might follow from the assumption that there is an impact in the phonological processing with age increasing (Shafto et al. 2012, a.o., for spoken languages). It is important to notice that these types of tests are commonly used to assess language impairment (Friedman et al., 2013 for an overview) and are therefore less sensitive than tests such as sign recognition with gating (Emmorey and Corina, 1990), identification and discrimination of parameters (Morford et al., 2008) or eye-tracking techniques (Lieberman et al., 2015; Thompson et al., 2013; Wienholz et al., 2019), which all reveal a significant difference between native signers and other populations of signers. Given the good performance observed across participants and languages in the lexical tasks we designed, we suggest that these tests might offer a reliable tool for clinical assessments of language impaired deaf signers. The data on typical population, here presented, could be used as baselines for assessing pathological populations.

### 3.2.2. Syntactic tests

In this section we present the tests we created within the SIGN-HUB project to assess morpho-syntactic comprehension across the three sign languages. The tests were language specific, but they were similar in design and, most importantly, the criteria to distinguish the populations investigated were the same.

We first present the tests on relative clauses and *wh*- questions, and we then describe the SL specific ones on role shift and directional verbs.

#### 3.2.2.1. Long distance dependencies: relative clauses and *wh*-questions

For head initial languages such as English it has been found that subject relative clauses are easier to understand than object relative clauses, and this is the case also for subject *wh*-interrogatives with respect to object *wh*-clauses (Friedman et al., 2009, a.o.). Such asymmetry, that goes under the name of Subject Advantage, has been accounted in various ways, with proposals pointing at resource-based effects related to structural distance (Frazier, 1987; Hawkins, 1999), intervention (Friedmann et al., 2009), linear distance (e.g., King and Just, 1991; Gibson, 2000) or, canonical order effects (Diessel and Tomasello, 2005), distribution-based effects (e.g., Mak et al., 2006), and prominence-factors (van Valin and Wilkins, 1996). Most studies point towards a universal Subject Advantage at the cross-linguistic level, but interestingly, most of them focus on head initial languages. In the SIGN-HUB project tests, LSF allows both SOV and SVO orders with preference varying across individuals (Hauser 2019), while LIS and LSC show a SOV order (Cecchetto et al., 2006; Quer, 2002). Moreover, among the three languages, different strategies are used to realize subject and object relative clauses and *wh*-constructions: LSF has head-external relative clauses and in-situ *wh*-interrogatives (Hauser, 2019), while LIS and LSC have head-internal relative clauses and *wh*-clauses with *wh*-movement to the right periphery of the sentence (Branchini & Donati, 2009; Cecchetto et al., 2009; Mosella, 2012; Quer et al., 2005). Other than providing new results to contribute to the debate of age of language exposure as a factor in language assessment, the tests also provide crucial data from a different modality on how to explain

the Subject Advantage from a theoretical point of view. We refer to Hauser et al. (2021a), Cecchetto et al. (2021) and Hauser et al. (2020b) for a detailed discussion of these conclusions.

Let us start with the presentation of the tests on relative clauses (RC) in LIS, LSC and LSF (cf. Giustolisi et al., 2019, for LIS, Zorzi et al., 2019, for LSC and Hauser et al., 2019, for LSF). The tests aimed at investigating the comprehension of subject and object relative clauses in a sentence-to-picture matching task based on Friedmann et al. (2009). In each picture, three characters were displayed: two identical and either performing an action or undergoing that action with respect to a third different character standing between them (Figure 3).



*Figure 3. Example of a three characters picture used in the RC test.*

The same picture was used to match a subject RC (i.e., 'Choose the lion that licks the dog') or an object RC (i.e., 'Choose the lion that the dog licks'). Participants were asked to choose one of the characters depending on the type of relative clause they were watching. Some of the pictures were used as controls, hence associated with a simpler request not including any relative clause (i.e., 'Choose the blue animal'). As already mentioned, all the sentences used in the experiments were constructed with the help of native consultants of the investigated sign language.

For each trial, participants saw first the stimulus video, automatically followed by the picture on which to click to provide their answer, like the one in (Figure 3) above. The request embedded a subject RC, or an object RC or, if it was a control item, a simpler sentence. For each language the test included from 45 to 70 items, among which from 40 to 56 were target items RCs, and were administrated in two blocks (see the Supplementary Material for details on the number of items and characteristics of the participants for each language). In (1)-(2) we can see an example of subject and object RC for LSC (1) and LSF (2). It is important to notice that LSC, as LIS, displays head-internal relative clauses in a head-final language, while LSF presents externally headed relative clauses in a head-initial language.[11] In LSC the relative marker is represented by the sign SAME (Mosella Sanz, 2012), while in LSF by the sign PI (Hauser and Geraci, 2017). The specific non-manual markers (NMMs) that indicate the use of a relative clause are not glossed in the examples.

(1) a. *Subject relative clause*

[11] In the glossed examples, each sign is glossed using small caps, letter indexes mark the referent the sign refers to or the locus in space assigned to the sign; as for number, '2' indicates 2nd person singular and '3', 3rd person singular. When written together on the sides of a verb, numbers and letters indicate the directionality of agreement of the verb. The type of clause or phenomenon is marked between brackets: RC stands for 'relative clause', while RS for 'role shift'. Finally, CL is the gloss for classifiers.

[RC SAME **LION**$_{\mathbf{i}}$ $_{i}$LICK$_{k}$ DOG$_{k}$] IX$_{2}$ CLICK [LSC]
'Click on the lion that licks the dog.'

b. *Object relative clause*
[RC SAME **LION**$_{i}$ DOG$_{k}$ $_{k}$LICK$_{i}$] IX$_{2}$ CLICK [LSC]
'Click on the lion that the dog licks.'

(2) a. *Subject relative clause*
… HAVE-TO CHOOSE **LION**$_{\mathbf{i}}$ [RC PI$_{\mathbf{i}}$ **__** $_{\mathbf{i}}$LICK$_{k}$ DOG$_{k}$]. [LSF]
'(You) have to choose the lion that licks the dog.'

b. *Object relative clause*
… HAVE-TO CHOOSE **LION**$_{\mathbf{i}}$ [RC PI$_{i}$ DOG$_{k}$ $_{k}$LICK$_{\mathbf{i}}$ **__**]. [LSF]
'(You) have to choose the lion that the dog licks.'

See Hauser et al. (2021a) for more details on the test itself and for the theoretical considerations related to it.

Another structure characterized by long-distance dependencies are *wh*-interrogatives (also called content questions). The tests developed for LIS, LSC and LSF aimed at assessing comprehension of subject and object questions (cf. Checchetto et al., 2019, for LIS, Zorzi et al., 2019, for LSC and Aristodemo et al., 2019, for LSF). In the three languages, 40 to 60 questions balanced across the various conditions were administrated in two blocks (see the Supplementary Material for details on the number of items and characteristics of the participants for each language).

The task was based on the same types of pictures just described for the relative clause test. Participants watched a video with a question and had to answer by pointing to the correct character in the three characters picture; See Figure 4 below.

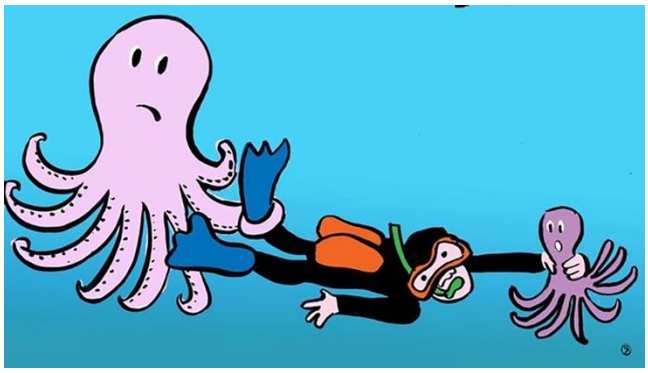


*Figure 4. An example of the three characters pictures used in the wh-questions test.*

Interestingly, LSF is a w*h*-in-situ language, while LIS and LSC show *wh*-movement to the right periphery of the sentence. In (3) we can see an example of who-questions and which-questions, subject and object, from LSF and LIS.

(3) a. *Subject who-question*
WHO$_{a}$ $_{a}$GRAB$_{b}$ MAN-DIVER$_{B}$ [LSF]
'Who grabs the diver?'

b. *Object who-question*
MAN-DIVER$_{a}$ $_{a}$GRAB$_{b}$ WHO$_{b}$ [LSF]
'Who does the diver grab?'

c. *Subject which-question*

DIVER CL:'diver'$_a$ GRAB$_a$ OCTOPUS WHICH [LIS]
'Which octopus grabs the diver?'

d. *Object which-question*
DIVER$_a$ $_a$GRAB$_b$ OCTOPUS$_b$ WHICH [LIS]
'Which octopus does the diver grab?'

For more details on the tests in LIS and LSF, see Cecchetto et al. (2021) for LIS and Hauser et al. (2021b) for LSF.

### 3.2.2.2. Modality specific phenomena: role shift and agreement

Two comprehension tests were created to investigate two constructions that are modality specific: role shift and the expression of spatial agreement through directional verbs. Role shift is commonly used in sign languages and is particularly interesting for its semantic properties; spatial agreement consists in a strategy expressing agreement through articulation in space of the trajectory associated with the verb. This phenomenon has been studied in other sign languages showing an important impact of AoE (Emmorey et al. 1995, Cormier et al. 2012, a.o.). The two tests were language specific but had a similar design across languages.

Let us start with the role shift tests (cf. Sala et al., 2019, for LIS, Zorzi et al., 2019, for LSC, and Aristodemo et al., 2019, for LSF). Role shift (RS) is a construction commonly used in sign languages to report utterances or thoughts from the perspective of an agent distinct from the utterance speaker (Quer, 2011).[12] It is signaled by specific NMMs that can slightly vary across languages, but that in general are characterized by body/head movement towards the locus in space assigned to the referent whose utterance or thought has been reported, and eye-gaze contact break with the actual addressee. Interestingly, when introduced by a verb like SAY, role shift displays indexical shift: within the scope of this verb, indexical expressions like the first-person pronoun (IX$_1$) retrieve their reference from the reported context.

One of the main goals of these tests was to assess the comprehension of pairs of sentences with and without RS with a first-person pronoun embedded under SAY. We can see an example in (4) and (5) in which the first-person pronoun is in the object position (in another condition the first-person pronoun was in subject position). For each language, the test included from 48 to 100 items, among which from 36 to 84 were target items with and without RS (see the Supplementary Material for details on the number of items and characteristics of the participants for each language). The test was administrated in two blocks. Each item was made of a series of slides. In the first one two pictures were shown side by side 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, in which the first-person pronoun referred to the actual signer (see Figures 5). Participants had no time limit to look at the pair of pictures. When ready, they had to press an arrow below the pictures. In the following slide, the target video was displayed in the center of the screen, with the pair of pictures still visible under the video. 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 examples reported below in (4) and (5) are from LSC.

i) Sentence with first-person pronoun in object position.

(4) **With RS:**
IX$_1$ ANIMAL ADORE. COLLEAGUE$_i$ TELL$_1$ [$_{RS\text{-}i}$ SECRETARY CAT $_3$CL: 'cat_give'$_1$].
'I love animals. My colleague told me: The secretary will give me a cat.'

[12] Our test did not include examples of so-called Action Role Shift, also called reported action.

(5) **Without RS:**

HOUSE GARDEN IX$_{1(poss)}$ CAT LIVE. IX$_1$ COLLEAGUE $_3$TELL$_1$ SECRETARY ONE CAT MORE $_3$CL: 'cat_give'$_1$.

'In my garden there are some cats living. My colleague tells me that the secretary will give me one more cat.'



*Figure 5. Example of an item with first-person pronoun in object position. The first screenshot represents the two pictures that were seen in the first slide. The one on the left matches the sentence with RS (My colleague told me: The secretary will give me a cat), whereas the one on the right matches the sentence without RS (My colleague tells me that the secretary will give me one more cat). The second screenshot shows the video sentence and the two clickable pictures. Importantly, the signer was always the same person and was clearly recognizable in the pictures.*

In addition to the condition in which the first-person pronoun was in object position (just illustrated) and to the condition in the first-person pronoun was in subject position, a third condition was added involving a first-person possessive.

As for the other tests presented so far, this study on RS was meant to give a contribution to the debate on the theoretical nature of this structure. See Aristodemo et al. (2020a) for further details, also on the design of the test for the three languages.

Let us turn now on the last test we are going to describe, which investigated the comprehension of agreement using directional verbs. This type of verb is characterized by the articulation of a trajectory in the signing space from the locus associated to an argument towards the position associated to another argument.

In this test, the target sentence containing an agreeing verb appeared on the screen right after a non-linguistic clip describing a situation with three characters. Participants had to judge whether the target sentence matched the situation described in the clip or not by clicking on a green or red sign respectively. When the sentence did not correctly describe the situation, this could be because reversed thematic roles were attributed to the characters, or because the wrong characters were involved in the situation. Sentences were always signed by character A, who was therefore the grammatical first person, to character B (the grammatical second person). Character B was also always present in every video. For each language the test included from 68 to 96 items, among which from 48 to 72 were target items (see the Supplementary Material for details on the number of items and characteristics of the participants for each language). We can see an example in (6) of the three conditions from LSC.

(6) Situation clip: character A is limping, and character B helps him.

a. Matching: second to first-person agreement
   *Character A signs*: IX$_{1A}$ LIMPING, IX$_{2B}$ $_{2B}$HELP$_{1A}$
   'I was limping and you helped me.'

b. Mismatch: thematic role inversion (first to second-person)

*Character A signs*: $IX_{2B}$ LIMPING, $IX_{1A}$ $_{1A}HELP_{2B}$
'You were limping and I helped you.'

c. Mismatch: wrong arguments selection (second to third-person)
*Character A signs*: JORDI LIMPING, $IX_{2B}$ $_{2B}HELP_{3C}$
'Jordi was limping and you helped him.'

Once again, see Aristodemo et al. (2021a) for an extensive discussion also from a theoretical perspective on the three sign languages.

### 3.3. Summary of results for syntactic tasks: long distance vs. SL specific

In all the tests the results were clear: a delayed AoE had a lifelong impact on individuals' language performance and/or competence.

As for the comprehension of *wh*-questions, in LIS natives outperformed non-native signers not only in object questions, that were expected to be complex, but also in control questions, which were easy (Cecchetto et al., 2021). Even in this simple task, a difference emerged, confirming permanent effects of delayed exposure to sign language. Similar results were found for LSC, where natives differed significantly from non-native signers independently from the type of question. For LSF, comparing language groups, a marginal difference was found between native and late learners, but a significant interaction emerged between this factor, the type of question and the subject/object condition. It was also found that the complexity provoked by object questions especially in which-questions is particularly affecting late learners of LSF (Hauser et al., 2021b). Importantly, in the three languages, early and late signers did not perform differently.

The same consistent results have been found in the comprehension of directional verbs across the three languages: natives outperformed non-natives in LIS in the mismatch conditions, while for LSC this was the case only in the match condition. In LSF, instead, native signers were more accurate than non-natives in both mismatch and match conditions. In general, no difference between early and late signers was found. For further preliminary results on LIS, LSF and LSC, see Aristodemo et al. (2020) and Aristodemo et al. (2021b).

The test on the comprehension of role shift also supports the results seen so far (Aristodemo et al., 2021a). In LIS, native signers outperformed early and late signers both when the first-person pronoun appeared in subject and object position, with RS and without RS. Also in LSF, native signers outperformed early signers in all types of sentences in both conditions. Moreover, native signers outperformed late signers in all sentences with RS. This was not the case for sentences without RS, but one might speculate that this is because the late signers who performed worse in RS preferred by default the no RS condition (see Aristodemo et al., 2021a, for a discussion). This might explain why late signers outperformed early signers in sentences without RS, and why the difference between late and native signers was not significant. In LSC, all groups had a good performance in sentences without RS. On the contrary, the performance in sentences with RS was more variable, but poor in the natives, and very poor in early and late signers. These results are attributed in the paper to a series of factors related to the RS stimuli NMMs that were relatively subtle and might not have been clearly perceived by non-natives.

Finally, the test on relative clauses provides further evidence about the impact of AoE, and the special status of natives. As for LSF, Hauser et al. (2021a) reported that for all three groups the difference between subject RCs (SRC) and object RCs (ORC) was significant, such that subject RCs were understood more easily. In the comprehension of ORCs, natives performed significantly better than late learners and performed better than early learners in SRCs, but not significantly so. No significant difference was found between early and late learners. We can see the data represented in Figure 6 and the analyses reported in Table 4.

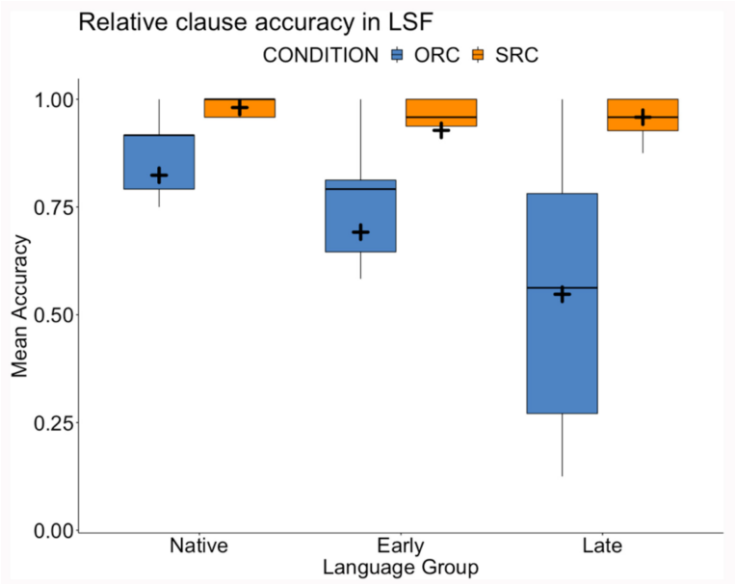



*Figure 6. LSF accuracy in object (blue) and subject relative clause (orange) comprehension for native, early, and late learners (Hauser et al. 2021, Figure 15).*

*Table 4. LSF pairwise comparison of accuracy across language group and conditions (SRC, ORC) (Hauser et al. 2021, Table 1 adapted).*

| **By condition** | **Est.** | **SE** | **z** | **p** |
|---|---|---|---|---|
| Native SRC vs. Native ORC | –3.374 | 0.544 | –6.204 | **<.0001** |
| Early SRC vs. Early ORC | –2.410 | 0.286 | –8.419 | **<.0001** |
| Late SRC vs. Late ORC | –3.659 | 0.337 | –10.861 | **<.0001** |
| **Population Natives vs. Early** | **Est.** | **SE** | **z** | **p** |
| Native SRC vs. Early SRC | 1.891 | 0.766 | 2.467 | **0.0136** |
| Native ORC vs. Early ORC | 0.927 | 0.557 | 1.664 | 0.0961 |
| **Population Natives vs. Late** | **Est.** | **SE** | **z** | **p** |
| Native SRC vs. Late SRC | 1.433 | 0.790 | 1.814 | 0.0697 |
| Native ORC vs. Late ORC | 1.719 | 0.563 | 3.053 | **0.0023** |
| **Population Early vs. Late** | **Est.** | **SE** | **z** | **p** |
| Early SRC vs. Late SRC | –0.458 | 0.631 | –0.725 | 0.4682 |
| Early ORC vs. Late ORC | 0.792 | 0.532 | 1.489 | 0.1365 |

In LIS, natives significantly outperformed early learners in SRCs, and they outperformed both early and late learners in ORCs. The difference between early and late learners was not significant. We can see the data represented in Figure 7 and the analyses reported in Table 5.

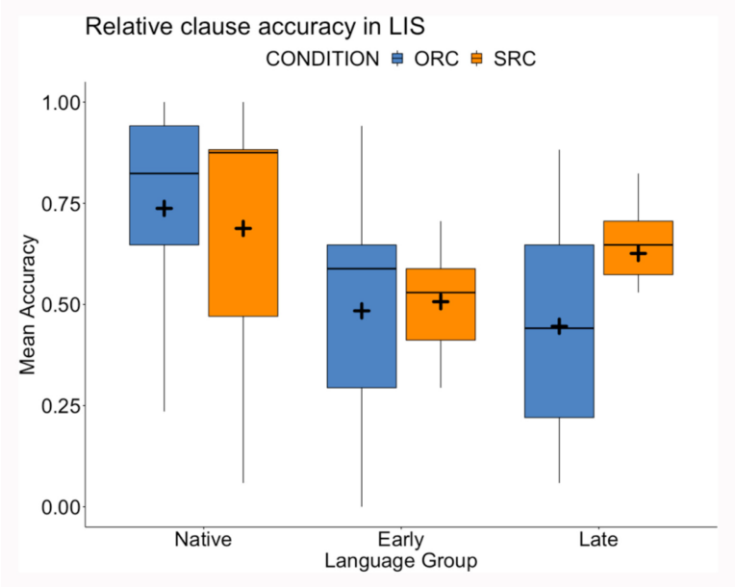



*Figure 7. LIS accuracy in object (blue) and subject relative clause (orange) comprehension for native, early, and late learners (Hauser et al. 2021, Figure 16).*

*Table 5. LIS pairwise comparison of accuracy across language group and conditions (SRC, ORC) (Hauser et al. 2021, Table 2 adapted).*

| **By condition** | **Est.** | **SE** | **z** | **p** |
|---|---|---|---|---|
| Native SRC vs. Native ORC | 0.321 | 0.226 | 1.422 | 0.1551 |
| Early SRC vs. Early ORC | –0.106 | 0.205 | –0.516 | 0.6061 |
| Late SRC vs. Late ORC | –0.864 | 0.220 | –3.920 | **0.0001** |
| **Population Natives vs. Early** | **Est.** | **SE** | **z** | **p** |
| Native SRC vs. Early SRC | 0.995 | 0.430 | 2.313 | **0.0207** |
| Native ORC vs. Early ORC | 1.422 | 0.434 | 3.276 | **0.0011** |
| **Population Natives vs. Late** | **Est.** | **SE** | **z** | **p** |
| Native SRC vs. Late SRC | 0.420 | 0.441 | 0.951 | 0.3414 |
| Native ORC vs. Late ORC | 1.605 | 0.444 | 3.615 | **0.0003** |
| **Population Early vs. Late** | **Est.** | **SE** | **z** | **p** |
| Early SRC vs. Late SRC | –0.575 | 0.447 | –1.288 | 0.1979 |
| Early ORC vs. Late ORC | 0.183 | 0.445 | 0.411 | 0.6808 |

As for LSC, the results obtained went even beyond our expectations about AoE affecting adults' performance, and raised interesting questions. Again, SRCs were significantly better understood than object RCs across all three groups. As for ORCs, the difference between late and early learners only approached significance, while there was no significant difference between natives and early learners. Late learners had a significantly lower performance than native learners. Interestingly, non-native learners were *below chance* when it came to ORCs, suggesting that non-natives interpreted ORCs as SRCs. We can see the data represented in Figure 8 and the analysis reported in Table 6.

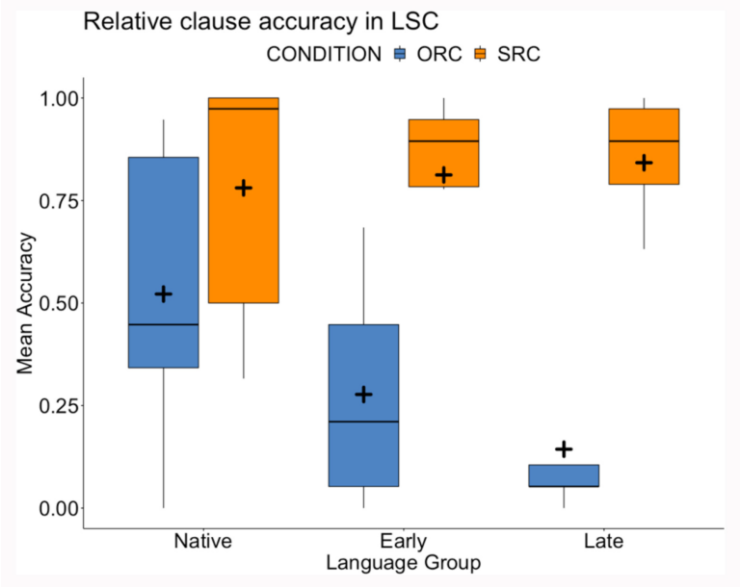



*Figure 8. LSC accuracy in object (blue) and subject relative clause (orange) comprehension for native, early, and late learners (Hauser et al. 2021, Figure 17).*

*Table 6. LSC pairwise comparison of accuracy across language group and conditions (SRC, ORC) (Hauser et al. 2021, Table 3 adapted).*

| **By condition** | **Est.** | **SE** | **z** | **p** |
|---|---|---|---|---|
| Native SRC vs. Native ORC | –1.605 | 0.250 | –6.433 | **<.0001** |
| Early SRC vs. Early ORC | –2.736 | 0.267 | –10.236 | **<.0001** |
| Late SRC vs. Late ORC | –4.316 | 0.361 | –11.954 | **<.0001** |
| **Population Natives vs. Early** | **Est.** | **SE** | **z** | **p** |
| Native SRC vs. Early SRC | –0.368 | 0.521 | –0.707 | 0.4795 |
| Native ORC vs. Early ORC | 0.762 | 0.502 | 1.520 | 0.1285 |
| **Population Natives vs. Late** | **Est.** | **SE** | **z** | **p** |
| Native SRC vs. Late SRC | –1.003 | 0.554 | –1.810 | 0.0703 |
| Native ORC vs. Late ORC | 1.708 | 0.553 | 3.088 | **0.0020** |
| **Population Early vs. Late** | **Est.** | **SE** | **z** | **p** |
| Early SRC vs. Late SRC | –0.634 | 0.520 | –1.219 | 0.2229 |
| Early ORC vs. Late ORC | 0.946 | 0.520 | 1.818 | 0.0691 |

As discussed in detail in Hauser et al. (2021a), this seems to represent an extreme case of AoE effect, where the difference in AoE produces a difference in grammar, not just in performance, with native signers having both subject RCs and object RCs in their grammar while non-native signers do not allow object RCs at all in LSC. We shall go back on the possible consequences of this finding in the next section.

## 4. Discussion

Summarizing the main findings of the tests described in the preceding section, we can conclude that a delayed AoE has a direct impact on syntactic competences. This conclusion holds both for those linguistic phenomena that are widely known to be sensitive to language acquisition disruption, such as the comprehension of long-distance dependencies (assessed here through relative clauses and content

questions), and for phenomena that are more specific to the signing modality, such as the comprehension of role shift and of spatial agreement (directional verbs). Interestingly, the same results (e.g., subject advantage in long-distance dependencies being affected by delayed AoE) hold across different sign languages, notwithstanding important syntactic differences across constructions. As for relative clauses, for example, similar results are reported for LSF, LIS and LSC, even if the strategy employed in these languages is superficially very different: relative clauses are head-external and postnominal in LSF, while they are head-internal and left extraposed in LIS and LSC.

On the other hand, lexical comprehension tasks do not exhibit the same degree of AoE effect, suggesting that lexical competences are overall more resilient and less sensitive to delayed AoE than syntactic competences. Again, this conclusion holds across languages (LIS, LSF, LSC) and tasks.

Remember that the question at stake in this paper is whether the traditional centrality that is assigned to natives in the linguistic literature makes sense in relation to the signing populations, where natives are a small minority, certainly not representative of the general population of signers. As for this more specific question, the results we just outlined in detail in the preceding section can be summarized in Table 7 below.

For each language, the first column in Table 7 indicates for every phenomenon investigated whether we found a significant difference in at least one condition of the tests between natives and non-natives. The second column summarizes for each phenomenon whether we found a significant difference between early and late learners.

*Table 7. Summary of the tests where natives significantly outperformed non-natives and where early learners significantly outperformed late learners in at least one condition of the tests.*

| | **Native vs Non-native** | | | **Early vs Late** | | |
|---|---|---|---|---|---|---|
| | **LIS** | **LSC** | **LSF** | **LIS** | **LSC** | **LSF** |
| **Lexical tasks** | □ | □ | □ | □ | □ | □ |
| **Relative clause comprehension** | □ | □ | □ | □ | □ | □ |
| ***Wh*-question comprehension** | □ | □ | □ | □ | □ | □ |
| **Role shift comprehension** | □ | □ | □ | □ | □ | □ |
| **Directional verb comprehension** | □ | □ | □ | □ | □ | □ |

Table 7 clearly indicates that language exposure from birth is an important factor in determining language competence in the syntactic phenomena we investigated. It also points at the importance of nativeness over simple earliness of first language exposure. These results have been obtained in sign languages that differ significantly in the syntactic domains under investigation. Nevertheless they are fully comparable as far as the effect of nativeness and AoE is concerned, since they have been obtained with comparable populations of signers divided according to the same criteria in three groups: natives, defined as signers exposed to sign language from birth and with at least one Deaf signing parent; early

learners, defined as been exposed to sign language between the age of 1 and 5 (included); late learners, defined as been exposed to sign language between the age of 6 and 15 years.

### 4.1. Natives are different

In all the phenomena that were investigated, a significant difference emerged between natives and early learners. This pattern appears to strongly confirm that there is a categorial effect of being native that goes beyond simple AoE, a more continuous measure. There are at least two possible interpretations for this finding, not necessarily mutually exclusive.

A first interpretation is that being a native signer goes beyond timing of exposure, and determines the quality and quantity of the input: natives are likely to be the only population which is exposed in a natural environment to an enriched input, which might be lacking in school environments, where non-natives are usually exposed to sign language. It is thus likely that the better performance of natives is related to this qualitative and quantitative difference in the input received.

While this is certainly true, it cannot be the whole story. First of all, keep in mind that even Deaf parents are not a uniform class, and many might have themselves been exposed to sign language at a late period in life, thus providing an input that is not qualitatively different, at least as far as pure linguistic properties are concerned, to the input the general population is exposed to (cf. Lillo Martin, 2021, and Singleton & Newport, 2004). Second, this "qualitative/quantitative" explanation would not extend to other findings pointing at a privilege of those children who are very early exposed to language as opposed to early exposed ones, no matter the family environment they are immersed into.

Friedmann & Szterman (2005) studied the competence in Hebrew of a group of hearing-impaired Hebrew-speaking (hence orally trained) children, all growing in hearing families under very similar circumstances. They found that individual performance in comprehension of long-distance dependencies in Hebrew was strongly correlated with the age of intervention: only children who received hearing aids before the age of 18 months performed well in the comprehension tasks. No other factors, such as the degree of hearing loss or the type of hearing device, significantly affected their performance. These findings indicate that something critical happens between birth and 1,5 years of age for syntax: in other words, they suggest that the critical period for first language syntactic competence is very early.

Friedmann & Rusou (2015) discuss the important issue of the effect of AoE in syntactic competences in a review paper, where they underline that most of the studies of a critical period for language acquisition test the acquisition of a second language, when one language has already been acquired. They suggest that a critical period for acquiring a first language is crucially different and earlier in time, and that for the acquisition of syntax it is the first year of life. While these results were only available until now with respect to spoken language inputs, our contribution confirms the existence of this critical threshold also for sign language, which is not surprising considering that sign languages are natural languages just as any other, governed by the same bioprogram.

Be that as it may, our conclusion has important practical consequences that should be underlined in the most explicit way. Whether hearing aided or not, in order to guarantee unhindered language acquisition, deaf children should be exposed to sign language as early as possible, ideally from birth.

### 4.2. But maybe not too different

A question that we have not yet discussed is whether the lower performance that we have captured in 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-natives but the internal grammar is the same). Take the Subject Advantage in long-distance dependencies. Our data show that this effect is stronger in non-natives than in natives. In the acquisition literature, the fact that

the Subject Advantage in RCs and *wh*-questions gets reduced with age in simple picture matching tasks has been interpreted in terms of lower computational resources in young children. A similar explanation might be adopted here. Comprehending a first language acquired with a delay involves a bigger effort and this emerges in complex tasks. We also saw that a co-factor determining the particularly low performance of LSC non-natives in the role shift comprehension task is the fact that in LSC stimuli NMMs were relatively subtle and might have escaped to non-natives. This as well goes in the direction of a performance account.

If this were all we found, we could conclude that native signers are different in that their performance is not affected by scarcity of resources, and they are more reliable as a source of linguistic information because their performance more directly reflects their grammatical competence. However, if we take a closer look at LSC for the relative clauses task, the picture appears to be different. In this language we found that the Subject Advantage is so strong as to take the shape of a categorical difference between the grammar of native signers and that of non-native signers, who systematically misunderstand object RCs. The overall results suggest that while native signers have both subject RCs and object RCs in their grammar, non-native signers do not allow object RCs at all in LSC. The fact that different varieties of languages realize different steps of the Accessibility Hierarchy of Keenan & Comrie (1977), which states that subject positions are more accessible than object positions in relativization, should not come as a surprise given the exceptional circumstances of access to language experienced by a large part of the deaf population. In fact, this finding, which replicates language internally the conclusion based on the typological literature, appears as an extreme case of AoE effect.

If this is true, however, the question of the reliability of native signers gets partially reversed: if they sign a qualitatively different language, that is indeed a tight minority language within the community of signers, how can we capitalize on their language for description, pedagogical tools, standardization procedures, or language assessment? As for the latter, our findings advocate for the development of specific baselines at least distinguishing native from non-native signers. As for language description and its practical uses, our findings suggest that the common practice of relying exclusively on native signers should be complemented with a careful consideration of possible variations in different populations, crucially related to AoE.

## 5. Conclusions

In this paper we report about a large-scale cross-linguistic study assessing comprehension across different sign languages and different syntactic and lexical phenomena to investigate the notion of native signer. By relying on the same criteria to define native, early and late signers, we were able to provide clear evidence that being exposed to sign language from birth has a permanent effect on language competence. In all the syntactic tasks that were administered, natives significantly outperformed non-native signers, no matter whether they were early or late learners. No strong effect of AoE was observed as far as lexical tasks were concerned.

While these results confirm that natives perform differently from non-natives, early learners included, they also suggest that at least for some phenomena and for some languages (and in particular for relative clauses in LSC) non-native learners develop a grammar that is significantly and qualitatively different from that of natives. Overall, these results reaffirm the importance of native signers within the signing community, but also challenge the generalized use of the notion of native speaker/signer as the baseline for language description and language assessment.

## 6. Conflict of Interest

*The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.*

## 7. Author Contributions

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**Assessment tools**

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# *Supplementary Material*

*Table 1. Number of participants and items per language in the role shift comprehension tasks.*

| ROLE SHIFT (RS) TASK | | |
|---|---|---|
| LANGUAGE | PARTICIPANTS | EXPERIMENTAL ITEMS |
| LIS | Total 42<br>15 NATIVE (Mage=43, sd=6)<br>15 EARLY (Mage=47, sd=9)<br>12 LATE (Mage=50, sd=9) | 80 SENTENCES (40 WITH RS, 40 WITHOUT RS) + 20 CONTROL ITEMS<br>4 items removed (each item composed by a pair of sentences, one with RS and one without RS) 8 sentences removed (4 with RS and 4 without RS) |
| LSF | Total 43<br>14 NATIVE (Mage=39, sd=10)<br>15 EARLY (Mage=34, sd=7)<br>14 LATE (Mage=40, sd=13)<br>1 late removed in the analysis | 60 SENTENCES (30 WITH RS AND 30 WITHOUT RS) + 24 CONTROL ITEMS<br>2 sentences removed (1 with RS and 1 without RS) |
| LSC | Total 39<br>13 NATIVE (Mage=42, sd=13)<br>15 EARLY (Mage=51, sd=11)<br>11 LATE (Mage=53, sd=8) | 100 SENTENCES (42 WITH RS AND 58 WITHOUT RS)<br>3 items removed (each item composed by a pair of sentences, one with RS and one without RS) |

*Table 2. Number of participants and items per language in the agreement comprehension tasks.*

| AGREEMENT TASK | | |
|---|---|---|
| LANGUAGE | PARTICIPANTS | EXPERIMENTAL ITEMS |
| LIS | Total 42<br>15 NATIVE (Mage=43, sd=6)<br>15 EARLY (Mage=47, sd=9)<br>12 LATE (Mage=50, sd=9)<br>- 1 native and 2 early removed in the analysis | 72 SENTENCES (18 MATCH, 36 AGREEMENT MISMATCH, 18 CONTROL)<br>1 item removed (each item composed by two sentences, one match and one mismatch) and 1 control removed |
| LSF | Total 43<br>14 NATIVE (Mage=39, sd=10)<br>15 EARLY (Mage=34, sd=7)<br>14 LATE (Mage=41, sd=13)<br>– 1 early and 3 late removed in the analysis | 68 SENTENCES (24 MATCH, 24 AGREEMENT MISMATCH, 20 CONTROL) 1 item removed (each item composed by two sentences, one match and one mismatch) |
| LSC | Total 37<br>12 NATIVE (Mage=40, sd=12)<br>14 EARLY (Mage=51, sd=11)<br>11 LATE (Mage=53, sd=8)<br>- 2 early and 1 late removed in the analysis | 96 SENTENCES (24 MATCH, 48 AGREEMENT MISMATCH, 24 CONTROL) |

*Table 3. Number of participants and items per language in the relative clauses comprehension tasks.*

| RELATIVE CLAUSES (RC) TASK | | |
|---|---|---|
| LANGUAGE | PARTICIPANTS | EXPERIMENTAL ITEMS |
| LIS | Total 39<br>15 NATIVE (Mage=47, sd=9)<br>13 EARLY (Mage=50, sd=9)<br>11 LATE (Mage=43, sd=6)<br>- 2 participants removed in the analysis | SENTENCES (20 SUBJECT RC, 20 OBJECT RC), 12 CONTROL repeated in each block.<br>4 items removed. |
| LSF | Total 42<br>13 NATIVE (Mage= 36, sd=9 )<br>15 EARLY (Mage=34 , sd=7 )<br>14 LATE (Mage=38 , sd=10 )<br>- 1 participant removed in the analysis | SENTENCES (28 SUBJECT RC, 28 OBJECT RC), 14 CONTROL repeated in each block<br>4 items removed. |
| LSC | Total 34<br>12 NATIVE (Mage=40, sd=11)<br>11 EARLY (Mage=49, sd=11)<br>11 LATE (Mage=53, sd=8)<br>- 5 participants removed in the analysis | SENTENCES (20 SUBJECT RC, 20 OBJECT RC, 10 CONTROL)<br>1 item removed. |

*Table 4. Number of participants and items per language in the wh- comprehension tasks.*

| WH- TASK | | |
|---|---|---|
| LANGUAGE | PARTICIPANTS | EXPERIMENTAL ITEMS |
| LIS | Total 44<br>15 NATIVE (Mage=43, sd=6)<br>16 EARLY (Mage=48, sd=9)<br>13 LATE (Mage=50, sd=9)<br>- 1 early and 1 late removed in the analysis | 52 WHICH QUESTIONS (20 SUBJECT 20 OBJECT, 12 CONTROL) |
| LSF | Total 43<br>14 NATIVE (Mage= 36, sd=9 )<br>15 EARLY (Mage=34 , sd=7 )<br>14 LATE (Mage=40 , sd=13 ) | 32 WHICH QUESTIONS (16 SUBJECT, 16 OBJECT), 30 WHICH QUESTIONS (15 SUBJECT, 15 OBJECT), 14 CONTROLS (= WHERE QUESTIONS) REPEATED IN EACH BLOCK. |
| LSC | Total 44<br>12 NATIVE (Mage=41)<br>10 EARLY (Mage=50.5)<br>9 LATE (Mage=53)<br>- 5 participants removed in the analysis | 52 QUESTIONS (10 WHO SUBJECT, 10 WHO OBJECT, 10 WHICH SUBJECT, 10 WHICH OBJECT, 12 CONTROL) |

*Table 5. Participants and items in the lexical comprehension tasks with phonological distractors.*

| LEXICAL COMPREHENSION TASK WITH PHONOLOGICAL DISTRACTORS | | |
|---|---|---|
| LANGUAGE | PARTICIPANTS | EXPERIMENTAL ITEMS |
| LIS | Total 41 participants<br>15 NATIVE (Age: mean 42, sd 6.1)<br>15 EARLY (Age: mean 47, sd 9.4)<br>11 LATE (Age: mean 50, sd 9.3) | N=22 |
| LSF | Total 43<br>14 NATIVE (Mage= 36, sd=9 )<br>15 EARLY (Mage=34 , sd=7 )<br>14 LATE (Mage=40 , sd=13 ) | N=21 |
| LSC | Total 38<br>12 NATIVE (Mage=41 , sd=13 )<br>15 EARLY (Mage= 51, sd=11)<br>11 LATE (Mage=54 , sd=7 ) | N=23 |

*Table 6. Participants and items in the lexical comprehension tasks with semantic distractors.*

| LEXICAL COMPREHENSION TASK WITH SEMANTIC DISTRACTORS | | |
|---|---|---|
| LANGUAGE | PARTICIPANTS | EXPERIMENTAL ITEMS |
| LIS | Total 42<br>15 NATIVE (Mage=43, sd=6)<br>15 EARLY (Mage=48, sd=9)<br>12 LATE (Mage=50, sd=9 | N=18 |
| LSF | Total 43<br>14 NATIVE (Mage= 36, sd=9 )<br>15 EARLY (Mage=34 , sd=7 )<br>14 LATE (Mage=40 , sd=13 ) | N=18 |
| LSC | Total 40<br>12 NATIVE (Age: mean 41, sd 13)<br>15 EARLY (Age: mean 51, sd 10)<br>13 LATE (Age: mean 53, sd 8) | N=18 |