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REGULAR ARTICLE

A subject advantage in covert dependencies: The case of *wh*-question comprehension in French Sign Language

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Abstract

Studies on sentence processing have shown that, as with all A-bar dependencies, content questions involving *wh* movement display a subject advantage. Very little is known, however, about *wh*-in-situ questions. The aim of this article is to fill this gap and explore whether a subject advantage can be found in *wh*-in-situ questions. We report the results of a sentence-to-picture matching task using in-situ *wh* questions in French Sign Language. Three adult populations with different ages of exposure to sign language were studied. Results show that comprehension of *wh*-in-situ questions in French Sign Language does display a subject advantage. We argue that this is relevant for the analysis of *wh* in situ, supporting a covert-movement analysis against alternatives involving some form of (unselective) binding. Moreover, comparison of our three populations shows that delayed exposure to language has an impact on the comprehension of *wh* questions, confirming that early language deprivation affects language competence in adulthood.

KEYWORDS

French Sign Language, *wh*-in-situ questions, subject advantage, age of first language exposure

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1 | INTRODUCTION: *WH* QUESTIONS IN FRENCH SIGN LANGUAGE

Both in spoken languages and sign languages (Zeshan 2004) content questions typically contain specialized expressions, so-called *wh* expressions, that identify the constituent that is questioned. The main typological divide across languages and modalities is related to the position of the *wh* expression: it can either be dislocated to a peripheral position (as in English *What did John eat?*) or simply left in situ in the position where it receives its theta role (as in Chinese *Xiaoming chi-le shenme?* = Xiaoming ate what). Some languages appear to have both options, such as French (as in *Qu'as-tu mangé* = what have you eaten or *Tu as mangé quoi* = you have eaten what). Besides this common dichotomy, there is a striking difference between sign languages and spoken languages concerning the position that interrogative phrases are dislocated to, a difference that has attracted much attention (Cecchetto et al. 2009, Kelepir 2021): while in the overwhelming majority of spoken languages interrogative phrases are either in situ or at the *beginning* of the clause, in all sign languages studied so far interrogative phrases can be found either in situ or dislocated to the *end* of the clause; in some, doubling of *wh* phrases and sentence-initial *wh* phrases can also be found (Zeshan 2004).

French Sign Language (LSF) is no exception and allows both strategies. The preferred option is the in-situ strategy illustrated in (1); this is the strategy that our study intends to examine.^{1,2}

- | | | |
|-----|---|------------------|
| (1) | a. WHO SCRATCH CAT?
'Who scratched the cat?' | Subject question |
| | b. CHILD SCRATCH WHO?
'Who did the child scratch?' | Object question |
| | c. CHILD SCRATCH [CAT WHICH]?
'Which cat did the child scratch?' | Object question |
| | d. [CAT WHICH] SCRATCH CHILD?
'Which cat scratched the child?' | Subject question |

However, the alternative with the *wh* sign displaced to a clause-final position is also possible in LSF. To begin our discussion of this alternative and how to exclude it, note that the adverb *YESTERDAY* in LSF generally appears at one edge of the clause, preferably at the end:

- | | |
|-----|--|
| (2) | a. YESTERDAY MARY BUY VASE.
'Mary bought a vase yesterday.' |
| | b. MARY BUY VASE YESTERDAY. |
| | c. *MARY YESTERDAY BUY VASE. |

We use this property as a marker of the clause edge, indicating whether an element lies within or outside of the clause. The possible positions of *YESTERDAY* in *wh*-in-situ questions are shown in (3), while its possible positions in *wh*-movement questions are shown in (4).

¹LSF allows both SVO and SOV orders, with preference varying across individuals (Hauser 2019). In the present study all the experimental items followed the SVO order, like the examples in (1).

²Following standard conventions in sign-language linguistics, glosses are given using small caps. Pronouns are indicated with the gloss IX (an abbreviation of *index*) followed by a number for first, second, or third person. Subscript letters (*a*, *b*, *c*, etc.) indicate in which area of the signing space a particular sign is made.

- | | | |
|--------|--|------------------|
| (3) a. | WHO SCRATCH CAT (YESTERDAY)?
'Who scratched the cat (yesterday)?' | Subject question |
| b. | CHILD SCRATCH WHO (YESTERDAY)?
'Who did the child scratch (yesterday)?' | Object question |
| c. | CHILD SCRATCH [CAT WHICH] (YESTERDAY)?
'Which cat did the child scratch (yesterday)?' | Object question |
| d. | [CAT WHICH] SCRATCH CHILD (YESTERDAY)?
'Which cat scratched the child (yesterday)?' | Subject question |
| (4) a. | SCRATCH CAT (YESTERDAY) WHO?
'Who scratched the cat (yesterday)?' | Subject question |
| b. | CHILD SCRATCH (YESTERDAY) WHO?
'Who did the child scratch (yesterday)?' | Object question |
| c. | CHILD SCRATCH (YESTERDAY) CAT (YESTERDAY) WHICH?
'Which cat did the child scratch?' | Object question |
| d. | _a CHILD SCRATCH CAT (YESTERDAY) _a WHICH?
'Which child scratched the cat?' | Subject question |

As shown in (4c) and (4d), clause-final *wh* signs may leave their nominal restriction in situ; but the dependency between the NP restriction and the *wh* element is then signaled by agreement in location, as shown explicitly in (4d).

An important issue is whether questions involving a postverbal *wh* element might be ambiguous in *interpretation*, that is, interpretable in principle both as in-situ *object* questions and as *wh*-movement *subject* questions. Word order and the obligatory-agreement facts illustrated in (4d) suggest that *wh* questions are never ambiguous in this way in LSF: a postverbal *wh* element can only be interpreted as part of an object question, unless special agreement markers are put in place, as in (4d).³

A different issue is whether questions involving postverbal *wh* elements, though only interpretable as object questions, might nevertheless be *derivationally* ambiguous: in other words, whether the sign strings observable in (4b) and (4c) (omitting the disambiguating YESTERDAYS) can be parsed according to both a *wh*-movement strategy and an in-situ strategy. A comprehensive study of *wh* questions in LSF is still missing (though see Geraci 2017), but based on the distribution of these two types of questions and on observations about other sign languages (American Sign Language: Neidle 2002, Abner 2011; Brazilian Sign Language: Nunes & Quadros 2005; Italian Sign Language: Cecchetto et al. 2009, Branchini et al. 2013), we believe that the in-situ strategy is the default strategy while *wh* movement is marked and restricted to specific pragmatic conditions. This means that given an out-of-the-blue or broad-focus context, only the in-situ strategy is available. This is confirmed by the examples in (3) and (4), where the distribution of the adverb YESTERDAY clearly signals whether the *wh* element has been moved (hence following the adverb) or not (hence preceding the adverb). This is also confirmed by (5), in which the insertion of the temporal adverb in prefinal position, which forces a movement analysis, is

³As will be detailed in section 4.2 when describing the experimental materials, unequivocal interpretation of the stimuli in our experiment was further enforced through the use of appropriate contexts and the clear use of spatial location to mark grammatical function (with the subject realized close to the body, leaning backwards, and the object realized away from the body, leaning forwards).



FIGURE 1 Nonmanual marking in a *wh* question in LSF [Color figure can be viewed at wileyonlinelibrary.com]

considered ungrammatical, thus showing that *wh* movement is not always available where the in-situ strategy is.

- (5) a. *CAT SCRATCH YESTERDAY WHO? *Wh*-moved object questions
 Intended: 'Who did the cat scratch?'
 b. *KING BRUSH YESTERDAY SOLDIER WHICH?
 Intended: 'Which soldier did the king brush?'

We take this observation to show that sentences including a postverbal *wh* sign are analyzed as in-situ object questions under normal conditions. Based on this conclusion, we were able to build a test assessing the comprehension of subject and object questions in LSF as unambiguously in-situ questions.

In addition to containing *wh* signs (which range across the full expected paradigm—'who', 'what', 'which', 'when', 'where', 'why'—and beyond, including interrogative words literally meaning 'do what' and 'what age'), *wh* questions in LSF are also characterized by a set of nonmanual markers, mostly co-occurring with the *wh* constituent or occasionally spreading over larger portions of the sentence. These markers are illustrated in figure 1: they include furrowed eyebrows and squinted eyes.⁴ The constraints driving the spreading of nonmanual markers in LSF and their possible impact on interpretation are not yet studied (but see Neidle et al. 2000 on American Sign Language, Cecchetto et al. 2009 and 2015 on Italian Sign Language and Finnish Sign Language, and Alba de la Torre 2016 for a general discussion). For this reason, we kept the realization of nonmanual markers constant in our experiment, co-occurring with the *wh* constituent only.

While *wh* questions in sign languages are rather well documented in descriptive and theoretically oriented work (see Petronio & Lillo-Martin 1997, Neidle 2002, Aboh et al. 2005, Lillo-Martin & Quadros 2006, Abner 2011, Branchini et al. 2013, and Geraci et al. 2015, among others), the way these structures are processed and comprehended in the signing modality is still mostly terra incognita. The first aim of this article is to help expand our knowledge of how these structures

⁴Per standard conventions, a line above the glosses in a sentence signals the presence of nonmanual marking and indicates its extension. The label above that line describes its grammatical function. We did not conduct any systematic analysis of the role of nonmanual markings in our study. We will not indicate them in the examples we discuss.

are treated across modalities by investigating how questions are comprehended by different populations of LSF signers. The second contribution this article aims at concerns *wh* in situ: with our study we want to verify whether the comprehension of *wh*-in-situ questions is biased by the same asymmetries that have been reported for *wh*-movement questions, hence bringing a piece of experimental evidence into the theoretical debate concerning the existence of covert movement and the general analysis to be given to *wh*-in-situ questions. The third goal is to investigate the impact of age of first language exposure on the comprehension of complex syntactic structures, questions in particular, by comparing three groups of deaf signers with different ages of exposure to (sign) language.

The rest of the article is organized as follows. Section 2 presents a survey of what we know about the comprehension of interrogatives and other A-bar dependencies and addresses a number of questions concerning in particular *wh*-in-situ questions (section 2.1) and the subject advantage (section 2.2). Section 3 reports the main results in the literature about the impact of first language exposure on signing populations. Section 4 presents our study. Section 5 discusses our main results and concludes the article.

2 | COMPREHENDING QUESTIONS

The issue of how individuals comprehend different types of questions and other long-distance dependencies has been central in the processing literature of the past 50 years. Here, we briefly summarize the main results concerning in-situ *wh* questions and the subject advantage.

2.1 | In-situ *wh* questions

Theoretical investigations of in-situ *wh* questions have mostly focused on Chinese and Japanese and have crucially maintained that in-situ *wh* questions involve a nonlocal dependency. For some scholars, this nonlocal dependency is literally the same as the one observed overtly in moved *wh* questions: the LF-movement analysis (C.-T. James Huang 1982) proposes that the only difference across languages is whether the movement operation that dislocates the *wh* phrase to its scope position happens abstractly at LF or concretely in overt syntax. Other approaches (Pesetsky 1987, Watanabe 1992) capitalize on the fact that covert dependencies appear to be somehow insensitive to island conditions, claiming that the difference between moved and in-situ *wh* questions is more profound: in-situ *wh* elements do not move but rather get their quantificational force by being bound by an operator in the periphery of the clause (see Cheng 2003 for a review of competing theoretical analyses). Recently, Bayer & Cheng 2017 claimed that *wh*-in-situ languages can be classified into two groups. The first group includes languages, like Japanese, that display an overt scope marker and where *wh* in situ is *not* subject to island effects. In this case, Bayer & Cheng argue that unselective binding is at play. The second group of *wh*-in-situ languages includes those languages, like Bengali, where there is no evidence for the existence of a scope marker and where *wh* in situ is subject to island effects. For these languages, Bayer & Cheng claim that covert movement is involved.

Although different in many respects, some of them directly relevant for our research, both of these approaches assume that in order to interpret a *wh* question you must establish an abstract long-distance dependency between the clause-peripheral position where the *wh* element gets its scope and the position within the clause where it receives its theta role.

The processing reflex of this abstract dependency has only relatively recently begun to attract attention (Frazier 1999, Frazier & Clifton 2000). The question is whether the same processing mechanisms that are deployed with overt dependencies are also employed in covert ones and hence whether processing *wh*-in-situ questions shows evidence of nonlocal-dependency formation, in spite of the fact that this happens covertly.

A number of studies have examined the processing of in-situ *wh* elements in Japanese. *Wh* phrases in Japanese are pronounced in situ and get their scope by associating with an overt scope marker attached to the verb. Miyamoto & Takahashi 2002 investigated the processing of *wh* elements inside embedded clauses. The authors manipulated whether the scope marker, *-ka*, occurred on the embedded verb or on the matrix verb. With a self-paced reading paradigm, they found that participants showed longer reading times on non-scope-marked embedded verbs (encountered earlier than matrix verbs given the head-final word order of Japanese) than on verbs in this position bearing *-ka*. Aoshima et al. 2004 extended and replicated these results. It thus appears that the distance of the dependency between a *wh* element and its scope position in Japanese has an impact on processing that is analogous to that observed in English. Ueno & Kluender 2009 found that longer *wh*-in-situ dependencies elicited a larger right-lateralized-anterior-negativity signal than shorter ones did, suggesting that more processing costs are associated with longer covert dependencies.

As Xiang et al. 2014 points out, however, it is difficult to conclude from these results that in-situ dependencies involve the construction of a covert dependency. The dependency between the *wh* element and its scope marker in Japanese is indeed overt, since the scope marker is morphologically expressed. Investigating the comprehension of Chinese in-situ *wh* questions is more interesting from this point of view, since no scope marker or any overt cue guides the interpretation of questions in this language and the covert long-distance dependency is a pure theoretical construct. Xiang et al., using the multiple-response speed-accuracy-tradeoff paradigm, show that Chinese *wh*-in-situ questions incur more processing costs than their declarative counterparts. Xiang et al. 2015, with two comprehension experiments, shows moreover that the process of linking an in-situ *wh* phrase and its scope position induces a similarity-based memory-interference effect if another clause-boundary position intervenes. In addition, a set of sentence-completion studies show that the production of *wh*-in-situ constructions is heavily modulated by the increased working-memory burden that results from planning and maintaining a nonlocal dependency.

LSF appears to be just like Chinese from this point of view, in that there is no overt scope marker at the relevant periphery of the clause, which is linearized on the right, and the dependency connecting the *wh* sign to its scope position is thus purely abstract.⁵

The first aim of this article is to contribute to the growing body of literature on the processing of *wh* in situ by adding the sign-modality perspective and to focus in particular on whether a very robust effect associated with long-distance dependencies, the so-called subject advantage, can be observed in *wh*-in-situ questions.

⁵Nonmanual markers have been claimed to function as scope markers in some sign languages with *wh* in situ, spreading obligatorily from the position of the *wh* sign to the right edge of the clause (Neidle 2002, Cecchetto et al. 2009), but this does not seem to be the case in LSF, where nonmanual markers never extend obligatorily beyond the *wh* sign itself and spreading appears to be optional. To be on the safe side, in the experiment that we will discuss in section 4, all the items exhibited local nonmanual markers only overlapping with the *wh* sign, hence not possibly functioning as a scope marker of any kind.

2.2 | The subject advantage in questions and other A-bar dependencies

A well-known asymmetry that goes under the name *subject advantage* appears to characterize all A-bar dependencies, at least overt ones. Content questions are no exception, in that subject questions are in general easier to comprehend than object questions. Such an advantage is well documented in the adult-sentence-processing literature (Van Gompel 2013), but it also holds for children acquiring their first language: it has been demonstrated that comprehension of subject questions that contain reversible verbs is at ceiling by four years old while that of some object questions may still be challenging at seven years old, with differences across languages (see Guasti 2004 for a discussion). Turning to special populations, the comprehension and production of subject questions appears to be easier than the comprehension and production of object questions for children with language impairments under a variety of conditions (Van der Lely & Battell 2003, Deevy & Leonard 2004, Levy & Friedmann 2009). The same asymmetry is documented for individuals with aphasia (Grodzinsky 2000, Garraffa & Grillo 2008, Sheppard et al. 2015).

As to how to explain such an advantage, there is no general consensus. There are proposals that appeal to resource-based effects related to linear distance (e.g., King & Just 1991, Gibson 1998), canonical-order effects (Diessel & Tomasello 2005), distribution-based effects (e.g., Mak et al. 2002), and prominence factors (Van Valin & Wilkins 1996), and there are structural-hierarchy-based accounts that appeal to structural principles such as Minimal Attachment (Frazier 1987), the Minimal-Chain Principle (De Vincenzi 1991), filler-gap domains (Hawkins 1999), and Relativized Minimality (Hawkins 1999, Friedmann et al. 2009). These different accounts make different predictions about the crosslinguistic extension of the phenomenon. While they all predict a subject advantage in languages with *wh* movement to the beginning of the clause, like English, they differ in their predictions concerning other word orders and other question patterns.

In *wh*-movement questions of the English type, like (6) and (7), the basic idea from a processing point of view is that when the parser encounters the *wh* phrase, it starts searching for an appropriate thematic-role assigner—what Lyn Frazier called the “active-filler strategy” (Frazier & Flores d’Arcais 1989)—and posits a gap as soon as possible.

- (6) Which giraffe ___ licks the cow?
 (7) Which giraffe does the cow lick ___?

The subject advantage can be seen as a direct reflex of this active-filler strategy: the subject is closer than the object, and maintaining a shorter dependency is less costly and resource consuming. Notice that in (6) and (7) the subject gap is closer to the *wh* expression both linearly and structurally.

The reverse mechanism should apply for *wh* movement to the right, as in the marked strategy in LSF, which was presented in (4), partially repeated here.

- (8) a. ___ SCRATCH CAT WHO? Subject question
 ‘Who scratched the cat?’
 b. CHILD SCRATCH ___ WHO? Object question
 ‘Who did the child scratch?’

This time, the parser first encounters a gap and starts searching for a filler, that is, a *wh* element. Here structural and linear accounts differ. The subject gap in (8a) is linearly more distant from the

wh element than the object gap in (8b), but it might still be hierarchically closer if *wh* movement targets a CP-like position in the right periphery.⁶

The comprehension patterns of *wh*-to-the-right questions have not yet been investigated, and we were not able to inquire into the matter for this study given the marked status in LSF of the strategy in (8) (but see Cecchetto et al. 2022 for some results on comprehension patterns of *wh*-to-the-right questions in Italian Sign Language). The only studies concerning the processing patterns of A-bar dependencies where the gap precedes the filler focus on relative clauses, where typological variation allows us to tease apart the linear and structural analyses (see results on Korean in O'Grady et al. 2003, Lin & Bever 2006, and Kwon et al. 2013 but also on Japanese in Miyamoto 2003, on Turkish in Slobin & Zimmer 1986 and Özge et al. 2009, on Cantonese in Jiaying Huang & Donati 2019, on Wenzhounese in Hu et al. 2018, and on Mandarin Chinese⁷ in Lin & Bever 2006, Wu 2009, Jäger et al. 2015, Lau 2016, and Jiaying Huang 2019, among others). Some marginal controversy aside, most studies point towards a universal subject advantage, which in turn advocates for a structural approach. This conclusion has recently been confirmed for sign languages by a study on both internally and externally headed relative clauses, Hauser et al. 2021.

It has also been suggested that object questions (and object relative clauses) are more difficult, in SVO languages at least, because after movement the arguments in the sentence are no longer in canonical word order (Diessel & Tomasello 2005). This makes it more difficult to “guess” a meaning based on surface form. Subject questions are easier presumably because there are no overt word-order differences between the interrogative and declarative forms. The only apparent change is the substitution of the *wh* word for the subject, which is already in its required position at the front of the clause.

Across studies, the subject advantage has also been shown to be affected and modulated by a number of other factors (Vasishth & Lewis 2006), such as animacy and saliency (Mak et al. 2002, Traxler et al. 2005, Mak et al. 2006). Friedmann & Novogrodsky 2004 and Friedmann et al. 2009 show that object dependencies can become easier for children if the intervening subject is a pronominal subject instead of a full DP:

(9) I prefer the princess [that **you** draw ____].

Friedmann and colleagues explain this as an effect of Featural Relativized Minimality: while a full DP shares with the raised object the fact of having a lexical restriction (call it a [+NP] feature) and hence intervenes in the relativization dependency, a pronominal subject does not, resulting in a disjoint configuration not affecting the dependency.

Also, among object questions, *wh* questions with lexical restrictions (e.g., ‘which dog’) emerge significantly later in L1 acquisition than bare *wh* questions (e.g., ‘who’) and are associated

⁶There are diverging views as to what syntactic mechanism produces *wh*-to-the-right questions in sign languages (see Kelepir 2021 for an overview). Cecchetto et al. 2009 (in accord with Neidle et al. 2000) argues for rightward movement to spec,CP, this position happening to be to the right in sign languages (and the authors go on to propose an explanation for why modality should have an effect on the directionality of A-bar movement). Others (e.g., Petronio & Lillo-Martin 1997) analyze the phenomenon as due to a two-step derivation first moving the *wh* element to spec,CP in the left periphery and then moving the entire clause further left. Be that as it may, the predictions of the linear and structural accounts for processing are the same: under both types of analyses, the object gap is linearly closer to the *wh* element than the subject gap; under both analyses, the object gap is structurally more distant (i.e., more deeply embedded) from the *wh* element than the object gap.

⁷See Gibson 2000, Qiao et al. 2012, or Chen & Shirai 2015, among others, for additional data suggesting the existence of an object advantage in pronominal relative clauses.

with difficulty until about age seven in monolingual development across languages (see, e.g., Tracy 1994, Stromswold 1995, Avrutin 2000). It has been argued (e.g., Omaki & Lidz 2015, Martini et al. 2019) that this asymmetry can also be explained as a Featural Relativized Minimality effect: overt object ‘which’ questions, which have a lexical restriction ([+NP]), are subject to greater similarity-based intervention from the lexical subject (which is [+NP] as well) than bare *wh* phrases ([−NP]). On the other hand, Avrutin 2000 and 2006 suggest that since ‘which’ phrases require linking to specific sets of discourse entities while *wh* pronouns such as ‘who’ do not, computing mental representations for ‘which’ questions requires more computational resources than computing ‘who’ questions.

Little investigation has been done of whether there is a subject advantage in *wh*-in-situ questions. Some studies suggest that *wh*-in-situ object questions are easier to comprehend than *wh*-movement object questions at least in special populations (Van der Meulen et al. 2005, Draï & Grodzinsky 2006). One study, Arslan et al. 2017, investigated the comprehension of *wh* questions in individuals with aphasia who speak Turkish, a *wh*-in-situ language, and German, a *wh*-movement language. Arslan et al. examined six German-speaking and 11 Turkish-speaking individuals with aphasia using picture-pointing tasks and found that the Turkish speakers responded more accurately to object questions than to subject questions while the German speakers performed better for subject questions. Some investigations that might also be relevant involve the processing of internally headed relative clauses, where there is arguably the same kind of covert dependency that is involved in *wh*-in-situ questions. Studies in Korean (Lee 1991, Lee-Ellis 2011, Kim & O’Grady 2016), where both types of relatives are available, reveal that children produce more object relatives than subject relatives in the form of internally headed relative clauses whereas for subject relatives they prefer externally headed relative clauses, arguably involving overt movement. This pattern suggests that overt movement might be more difficult for children than covert movement. As for sign languages, Hauser et al. 2021 tested the comprehension of relative clauses across three European sign languages, two of which (Italian Sign Language and Catalan Sign Language) display internally headed relative clauses and one (LSF) externally headed relative clauses. A subject advantage was found across languages, suggesting that processing relatives involves processing a long-distance dependency regardless of the particular relativization strategy.

The second aim of our study is thus to determine whether *wh* questions in LSF display a subject advantage or not and to use our results (i) for insight into the nature of this phenomenon and (ii) as an indirect source of evidence regarding the analysis to be given to *wh* in situ in this language.

If the subject advantage is due to *structural* factors and covert dependencies activate the same processing strategy as overt dependencies, we would expect to observe a subject advantage in the comprehension of *wh* questions in LSF.

If on the other hand the subject advantage is due to a *linear* distance (and again covert dependencies activate the same processing strategy as overt dependencies), we would expect an object advantage, because the relevant periphery appears to the right in LSF.

If the subject advantage is instead due to *canonicity* effects, we would expect no asymmetry between subject and object questions in LSF, since both types of questions display a canonical word order. The same prediction holds if the subject advantage is a bias connected to the *retrieval of the gap* and not to some more abstract distance-dependency procedure, since no gap is present in LSF.

Moreover, an (unselective-) binding analysis of *wh* in situ would predict no Relativized Minimality effect in LSF, while a covert-movement analysis might be compatible with the

observation of fine-grained intervention effects modulated by the type of *wh* element ('who' vs. 'which').

3 | AGE OF FIRST LANGUAGE EXPOSURE

Early exposure to language is well known to be crucial to language acquisition and full language development (Mayberry et al. 2002). While early exposure within the family is the default situation for hearing babies, this is not the case for deaf babies. Less than 10% of deaf children are born into deaf signing families (Mitchell & Karchmer 2004) and can receive a linguistic input from birth. The vast majority of deaf babies are born into hearing families and are thus first exposed to a language they have no (immediate) access to, hence virtually to no language. As a consequence, most deaf children suffer from a delay in language exposure, more or less severe depending on a number of factors such as the age of diagnosis and the type of language intervention chosen by the parents (hearing aids and/or cochlear implants and consequent training in spoken language; exposure to sign language; both). A minority of deaf children are exposed to sign language shortly after diagnosis, but most encounter sign language later in life, often after the failure of oral training.

As a result, adult signers with prelingual deafness are a very heterogeneous population that includes native and nonnative signers, some of whom have experienced a severely delayed exposure to language.

Several studies investigate the impact of delayed language exposure on sign-language competence, reporting significant effects of age of exposure. We briefly report here the most significant findings, focusing on behavioral studies.

The first work on the topic dates back to the late 1980s and early 1990s and focuses on morphological competence. Newport 1988 reports that nonnative L1 signers differ from native signers in the morphological generalizations they make while acquiring verbs in American Sign Language; Emmorey et al. 1995 shows that only native signers, not late signers (mean age of exposure: 12 years), are sensitive to agreement errors. As for syntax, Mayberry 1993 shows that the performance of L1 signers decreases as age of exposure increases in a repetition task involving complex sentences. Interestingly, the same study reports that nonnative L1 signers had a lower score than nonnative L2 signers who acquired American Sign Language at the same age (i.e., children who had become deaf after they had acquired English: children with postlingual deafness). Effects of age of exposure have also been reported for phonological processes and lexical access (Emmorey & Corina 1990).

Later work confirmed and generalized the early findings. Using a timed grammatical-judgment task, Boudreault & Mayberry 2006 found that the performance of nonnative American Sign Language signers decreased with increasing age of exposure, both for early-acquired syntactic structures like simple sentences, negation, verbal agreement and for late-acquired syntactic structures like *wh* questions, relative clauses, and classifier sentences. Cormier et al. 2012 replicated these findings using a British Sign Language version of Boudreault & Mayberry's task. Cormier et al. found that accuracy decreased as age of exposure increased only for deaf signers exposed to British Sign Language between two and eight years of age (defined as early signers in the study). Age of exposure had no effect on signers exposed to British Sign Language between nine and 18 years of age (defined as late signers in the study). Considering that English reading performance was higher for these late signers, the authors suggest that their group of late signers

was probably composed of people who had English as L1 and acquired British Sign Language as L2.

The Sign-Hub Project (<https://thesignhub.eu>), of which this article is a byproduct, investigated systematically the effects of age of exposure on lexical and syntactic competence in deaf adults across European sign languages. The main finding is of a clear effect of age of exposure on morphosyntactic competence, with significant differences between signers exposed to sign language from birth and those exposed later, across languages and tests. Interestingly, in many cases the effect of late exposure takes the shape of a subject advantage, increasing with age of exposure; this is observed in relative clauses by Hauser et al. 2021 and in role-shift comprehension by Aristodemo et al. 2022.

Given these findings concerning the effects of age of exposure on language competence and their relevance for the investigation of the subject advantage in particular, a natural question is whether the comprehension of LSF *wh* questions is also affected by this factor. In order to answer this question, our study compares the comprehension of *wh* questions in LSF in three different populations of signers: natives, early learners, and late learners.

4 | THE PRESENT STUDY

This section presents our experiment on *wh*-question comprehension in LSF. We developed a sentence-to-picture matching task, which we administered to the three different groups of signers just mentioned. We had the following hypotheses.

- (10) a. If *wh* expressions in in-situ questions must, in order to be interpreted, establish a covert dependency that is structurally constrained, we expect to find a subject advantage in LSF.
- b. If this covert dependency is an instance of covert movement, subject to the same constraints as overt movement, including Featural Relativized Minimality, we further expect object ‘which’ questions to be more difficult to comprehend than object ‘who’ questions.
- c. Since, in general, age of exposure has an impact on the comprehension of long-distance dependencies, we expect native signers to outperform early and late signers and that more complex sentences should be particularly challenging for nonnative signers, late signers in particular.
- d. If the first hypothesis is correct, we thus further expect that the subject advantage in LSF should be stronger in nonnatives than in natives.

All the materials, data files, and scripts used for the analysis can be found on the Open Science Framework public repository at https://osf.io/paj9n/?view_only=c9eaff3ba5a541cf9829a7de59a82e56.

4.1 | Participants

Participants were selected according to four 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) LSF as the preferred means of communication, and (iv) absence of cognitive disabilities.



FIGURE 2 Example item from the Odd One Out cognitive task [Color figure can be viewed at wileyonlinelibrary.com]

TABLE 1 Number of individuals in each of the three groups of LSF signers; summary of biographical characteristics (age, age of exposure, and level of education); summary of performance on the Odd One Out test (cognitive z score, expressed as the mean and standard deviation of the participants' z scores)

Group	N	Age	Age of exposure	Level of education	Cognitive z score
Native	14	M = 39 y SD = 10 y		Median = university level	M = -0.21 SD = 0.91
Early	15	M = 34 y SD = 7 y	M = 3 y SD = 1 y	Median = university level	M = 0.19 SD = 1.09
Late	15	M = 41 y SD = 13 y	M = 9 y SD = 3 y	Median = high-school level	M = 0.01 SD = 1.01

To identify participants with potential cognitive problems, we used the Odd One Out test, a nonlinguistic cognitive test. The version of this test that we used (Aristodemo & Friedmann 2019) consisted of items made up of four pictures in a row: see figure 2 for an example. The task was to identify the incongruous element: in figure 2, the bee. The test consisted of 28 items preceded by two training items. For each participant a z score was calculated, based on the mean and standard deviation for their language group. The criterion for exclusion from the study was having a z score lower than -2.5.

All participants were divided into three groups: (i) native signers, who were exposed to sign language from birth (age of exposure = 0) and had at least one signing parent or close relative; (ii) early signers, who were exposed to sign language before entering primary school (age-of-exposure range: two to five; mean: three); and (iii) late signers, who were exposed to sign language during the years of compulsory education (age-of-exposure range: six to 15; mean: nine). Participants were recruited online, through social media. We collected data from 49 participants (40 in Paris and nine in Nantes). During the experiment session we also collected metadata regarding the participant's signing background (age of exposure to LSF; presence or absence of deaf relatives; modality of communication with parents, siblings, and other relatives; and type of education, whether oralist, bimodal, mostly LSF, or something else) through a questionnaire. The metadata were anonymized following the recommendations of the Research Ethics Committee of Paris Descartes University and the French National Commission on Informatics and Liberty. A profile of the three language groups is given in table 1.

Five participants were excluded from the study: one of them because his first language turned out to be Belgian Sign Language rather than LSF, four due to their very late age of exposure (after 15 years old). The remaining 44 participants (23 women, 21 men) were included in the study.

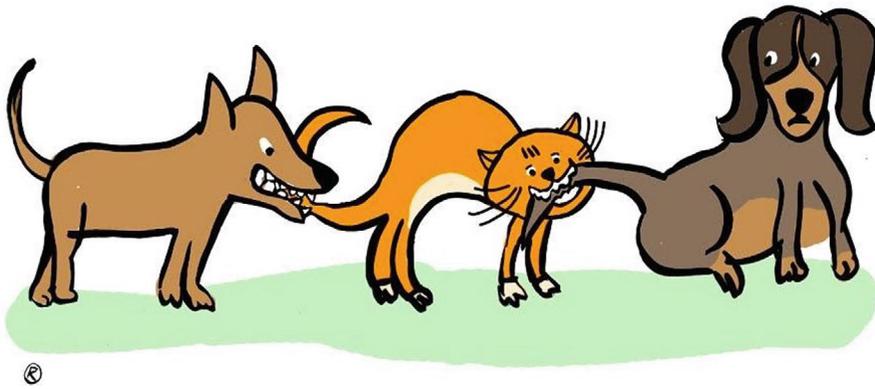


FIGURE 3 Picture used with the WHO questions in (11). The dog on the left matches the subject question, whereas the dog on the right matches the object question. [Color figure can be viewed at wileyonlinelibrary.com]

One ANOVA and two Kruskal–Wallis tests showed that the three groups did not differ with respect to age ($F(2) = 1.844, p = 0.17$), z scores on the Odd One Out test ($H(2) = 1.482, p = 0.48$), or level of education ($H(2) = 1.196, p = 0.55$).

4.2 | Materials

Our sentence-to-picture matching task (Aristodemo et al. 2019) involves WHO questions and WHICH questions (based on Friedmann & Novogrodsky 2004). The target questions consisted of both subject questions, where the *wh* phrase refers to the subject, and object questions, where the *wh* phrase refers to the object. All sentences were signed by a deaf native signer and videotaped.

There were 32 WHO questions, 16 subject questions and 16 corresponding object questions, and 30 WHICH questions, 15 subject questions and 15 corresponding object questions. Each pair of subject and object questions was matched with a picture displaying three characters: two of them, identical, each performing an action or undergoing that same action with respect to a third, different character standing in between them. See figures 3 and 4 for examples.

The target items were divided into two blocks, which were administered to each participant in two separate sessions. In each block, 14 fillers (WHERE questions) were added. The fillers were the same for the two blocks. The function of the fillers was threefold. (1) Since the fillers were simple, participants did not need to keep the same level of concentration throughout the whole experiment and could rest. (2) Performance on fillers was used as an objective measure of attention and overall comprehension. Participants who responded correctly to less than 75% of the fillers were excluded from the analysis. (3) Given that participants had to click on the left, middle, or right character in each picture when it was presented to them (see next section) and that the experimental design tended to bias participants toward always clicking on the left or right character, fillers provided some trials targeting the middle character. Half of the fillers targeted the middle character, while the other half targeted one of the side characters. The target items were also balanced, half targeting the right character and half the left one, with an equal representation of subject and object questions on both sides.

The order of the items was randomized.

The glosses of all experimental items are listed in the appendix, and the complete test is available upon request via <https://thesignhub.eu>.

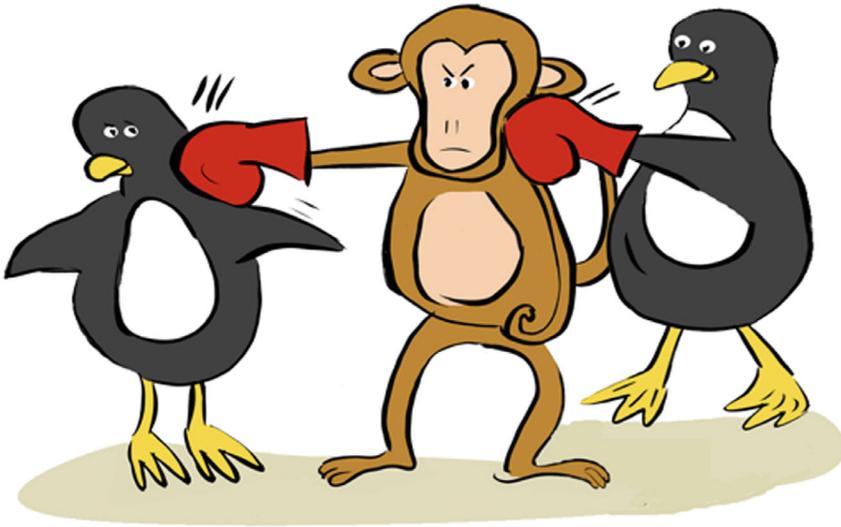


FIGURE 4 Picture used with the WHICH questions in (12). The penguin on the right matches the subject question, whereas the penguin on the left matches the object question. [Color figure can be viewed at wileyonlinelibrary.com]

Here we present one example of each type of stimulus. The WHO questions in (11) were used with the picture in figure 3, and the WHICH questions in (12) were used with the picture in figure 4. As shown, each WHO or WHICH question was preceded by a short context. With WHO questions, the context simply introduced the question. In the case of WHICH questions, the context introduced the characters, which was necessary given the D-linked nature of such questions.

(11) WHO questions

a. Subject

IX-1 QUESTION.

[_{back} WHO_a] aBITE_b CAT_b?

'I have a question: who bites the cat?'

Context
Stimulus

b. Object

IX-1 QUESTION.

CAT_a aBITE_b [_{forward} WHO_b]?

'I have a question: who does the cat bite?'

Context
Stimulus

(12) WHICH questions

a. Subject

HERE TWO PENGUIN, ONE MONKEY.

[_{back} PENGUIN_a WHICH_a] aPUNCH_b MONKEY_b?

'There are two penguins and one monkey.

Which penguin punches the monkey?'

Context
Stimulus

b. Object

HERE TWO PENGUIN, ONE MONKEY.

MONKEY_a aPUNCH_b [_{forward} PENGUIN_b WHICH_b]?

'There are two penguins and one monkey.

Which penguin does the monkey punch?'

Context
Stimulus



FIGURE 5 Picture used with the filler WHERE question in (13). The middle character (the mom) corresponds to the target answer. [Color figure can be viewed at wileyonlinelibrary.com]

The same two types of context were used for the fillers as well. The example in (13) was used with the picture in figure 5.

(13) Fillers

HERE TWO GIRL, ONE MOM.

MOM WHERE?

‘There are two girls and a mom. Where is the mom?’

Context

Stimulus

All items were made unambiguous using word order (see the discussion of *wh* in situ in LSF in the introduction). This unequivocal interpretation of the stimuli was further reinforced by a systematic use of spatial location on the horizontal axis, signaling the grammatical function of the *wh* element: subject *wh* phrases were realized close to the body, leaning backwards, while object *wh* phrases were realized away from the body, leaning forwards. This is indicated in the glosses of (11) and (12) using brackets. With agreement verbs (verbs that can modify their trajectory in order to incorporate subject and object agreement: Padden 1990) such as BITE and PUNCH, the grammatical function of the *wh* element was further signaled through agreement on the verb. This is shown in the glosses of (11) and (12) using letter indices. To avoid overcomplicating the glosses, we will not repeat these indications throughout all examples.

4.3 | Procedure

The test was built using software specifically developed for Sign-Hub. The task began with a video in LSF presenting instructions, followed by a short training phase. The duration of each testing session was around 20–25 minutes and was embedded within a larger testing session (around one hour and 30 minutes) during which the participants were undertaking other lexical and syntactic tests as well. Participants were left alone in the experiment room to perform the test on their own. They were sitting approximately 45 cm from the screen (22" display, 4:3 aspect ratio) and answered each question with a mouse click.

For each trial, participants saw the video stimulus automatically followed by the picture. To provide their answer, they had to click on a character in the picture. The stimulus video always started with a small context, as described in the previous section. The experimental procedure is illustrated in figure 6.

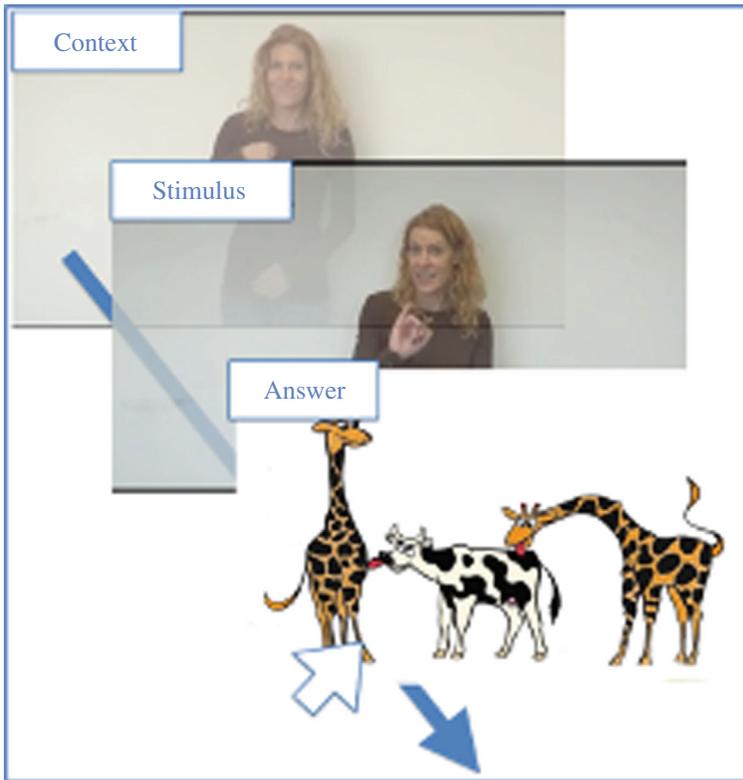


FIGURE 6 Picture illustrating the experimental procedure [Color figure can be viewed at wileyonlinelibrary.com]

4.4 | Results

4.4.1 | Data analysis

Data were shaped into a binary data set in which correct answers were coded as “1” and incorrect answers as “0.” We first conducted an item analysis, looking at items on which native signers performed under 50% on average, in order to identify and remove problematic items, likely to be affected by a technical issue (if this was the case, we removed the item altogether, both the subject and object versions of it). This led to the removal of three items (two WHO questions and one WHICH question), leaving 58 items (29 WHO questions and 29 WHICH questions) to analyze.

Results were analyzed with the R software (version 4.0.0; R Core Team 2005) using generalized linear mixed models from the binomial family via the `glmer` function in the package LME4 (Bates 2005). We studied the interaction between the three independent variables: language group (native, early, and late), condition (subject, object), and type of question (WHICH, WHO). Random variables were intercepts for participants and items.

4.4.2 | Accuracy

The results concerning accuracy are presented in figure 7.

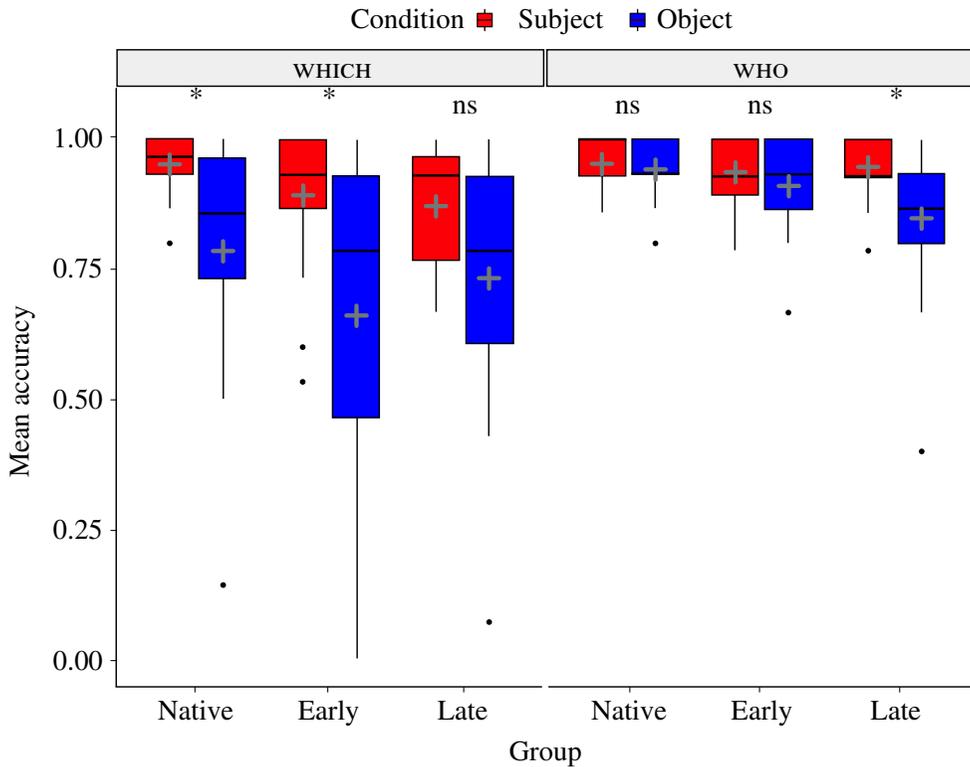


FIGURE 7 Accuracy of subject- and object-question comprehension in LSF, for native, early, and late signers, comparing WHICH and WHO questions. Average score per group is represented with a grey cross, median is the horizontal black line, and the statistical significance or nonsignificance of the difference between the conditions is indicated with * or *ns*, respectively, above each pair of columns. [Color figure can be viewed at wileyonlinelibrary.com]

As predicted from what we know about *wh*-movement questions, there is a strong difference linked to question type, with WHICH questions being understood significantly less accurately than WHO questions (estimate = 1.14571, SE = 0.26741, $p < .0001$). We also observe that accuracy on subject questions is significantly higher than on object questions (estimate = -1.13332 , SE = 0.14932, $p < .0001$) and that the two parameters strongly interact (estimate = 1.00227, SE = 0.30145, $p < .0001$). Finally, when we compare language groups, we find a marginal difference between native and late learners (estimate = -0.75802 , SE = 0.45266, $p = .094013$) but a significant interaction between this factor, the type of question, and the subject-object condition (estimate = -1.88732 , SE = 0.74106, $p = .010872$).

We can conclude that our study about accuracy reveals a significant subject advantage both in WHICH questions and in WHO questions, suggesting that covert A-bar dependencies are subject to the same bias that holds for overt A-bar dependencies. Our study also confirms that there exists a strong asymmetry between *wh* questions with lexical restrictions (WHICH questions) and bare *wh* questions (WHO questions), as found in acquisition and processing studies focusing on *wh*-movement languages. Finally, we found that the complexity provoked by object questions, especially object WHICH questions, particularly affects late learners of LSF. This result is yet another piece of evidence indicating that a delayed age of exposure has a lifelong impact on individuals' language competence.

TABLE 2 Number of incorrect clicks on a side character or on the middle character, by language group, type of question, and condition

Group	Question type	Condition	Side character	Middle character	Total
Native	WHICH	Subject	2	8	10
		Object	21	21	42
	WHO	Subject	2	7	9
		Object	3	9	12
Early	WHICH	Subject	10	14	24
		Object	53	18	71
	WHO	Subject	8	5	13
		Object	8	12	20
Late	WHICH	Subject	15	14	29
		Object	36	20	56
	WHO	Subject	7	4	11
		Object	7	27	34
Total			172	159	331

4.4.3 | Errors

We also performed a qualitative analysis of errors to better understand whether the different behavior of native and nonnative learners was due to simple performance or rather corresponded to different grammatical patterns, as has been found in late learners of Catalan Sign Language for relative clauses (Hauser et al. 2021). Participants could in principle make two types of errors in their answers. They could click the wrong *side* character, for example the wrong dog in figure 3 or the wrong penguin in figure 4, or they could click the *middle* character (for a question whose correct answers was one of the side characters), such as the cat in figure 3 or the monkey in figure 4. One possibility is that nonnative learners can interpret questions but have trouble identifying the correct grammatical function of the *wh* sign only because their grammar is different from that of natives (for example, *wh* questions are ambiguous for them). In that case we predict that they would correctly target a side character (since they understand what type of character the question is about) but would tend to pick the wrong one. This pattern would contrast with that observed with native signers, for whom *wh* questions are never ambiguous but who might make random mistakes in the test due to fatigue or lack of attention. If on the other hand errors are due to performance issues that are shared by natives and nonnatives but get worse with nonnatives, we would rather expect the errors to distribute more or less equally across side and middle characters and to pattern the same across language groups.

Unfortunately, since participants performed fairly well across all conditions, we did not have enough errors with which to conduct a statistical analysis in order to determine whether a pattern emerged in some language group. Table 2 gives the totals we obtained for each type of error (side or middle character) broken down by language group, condition, and type of question.

Both types of error are more or less equally attested, and for each type there are more errors in the object condition than in the subject condition, as expected. Both types of errors are more

frequent in WHICH questions than in WHO questions, again as expected. This suggests that the problem observed with nonnatives is a performance issue and not a grammatical difference.

The only puzzling fact concerns the distribution of the middle-character errors in late learners: there are slightly more errors of this kind in WHO questions (27) than in WHICH questions (20). We do not have an explanation for this asymmetry, which might disappear if more errors were to be made. It could be that the context preceding the question, which only in the case of WHICH questions contained an explicit reference to the fact that there were two side characters and one middle character, somehow helped late learners to focus on the former.

5 | DISCUSSION AND CONCLUSIONS

The first result of this article is that the comprehension of *wh*-in-situ questions in LSF displays a subject advantage. This is important evidence that the theoretical construct of covert dependency that syntacticians posit in *wh*-in-situ questions does indeed have a reflex in comprehension, the most classical one: the subject advantage.

This conclusion is reinforced by the fact that we observed in LSF the same asymmetry between question types that has been reported and discussed for spoken languages. The subject advantage is much stronger for WHICH questions than for WHO questions. This result suggests that in *wh* in situ there is a long-distance dependency that is processed and/or represented in a way that is similar enough to overt movement dependencies that it is biased by not only the subject advantage but also the ‘which’-versus-‘who’ divide.

Before going further in our discussion, let us briefly consider an alternative explanation. As we mentioned when introducing *wh* questions in LSF in the introduction and when describing the materials for the experiment (section 4.2), the questions contained in the data set were never ambiguous: in all cases word order clearly disambiguated whether a given item was a subject or object question. Still, the interpretation as a subject or object question was also conveyed and thus reinforced by spatial information: in subject questions the *wh* phrase was systematically located close to the body, which was leaning backwards; in object questions the *wh* phrase was systematically located away from the body, which was leaning forwards. Now, it is likely that non-native signers are less sensitive than native signers to spatial information and spatial agreement (Emmorey et al. 1995). Could this explain the pattern of results that we found? We believe that it cannot, since what would be expected would be a general decrease in performance, not, as we found, a selective difficulty with object questions.

Our results thus confirm the existence of a subject advantage with *wh*-in-situ questions. As such, they can contribute to the ongoing debate about the nature and causes of the subject advantage, challenging in particular reductionist accounts (see Lasnik 1999 for similar reasoning concerning island effects). Whatever the final explanation to be given to this bias, it has to be an explanation that holds for both overt and covert dependencies. This implies that the subject advantage cannot be reduced to surface properties such as the presence of an actual gap (there is no such gap here) nor to linear distance (there is no linear distance here) nor to canonical-word-order effects (in LSF both subject and object *wh* questions follow the canonical word order observed in declaratives).

One possible explanation for the subject bias and for the ‘who’-‘which’ divide is Relativized Minimality (Rizzi 1990), in line with Friedmann et al. 2009. In object questions, the subject structurally intervenes in the dependency, and the disruption/complexity it introduces in processing is a function of featural similarity. In object ‘who’ questions, a lexical subject shares with the filler

only a [+D] feature (both being nominal), resulting in a mild disruption. In object ‘which’ questions, the lexical subject and the filler share both a [+D] feature and a [+NP] feature (both having a lexical restriction), resulting in a more severe disruption. This line of explanation can hold only if we assume that covert dependencies imply the movement of the same phrase that is moved in overt dependencies.

Our results can therefore also contribute to the ongoing debate concerning the nature of the covert dependency associated with *wh*-in-situ questions. The Relativized Minimality explanation just sketched is compatible with the traditional LF-movement analysis (C.-T. James Huang 1982) or a more Minimalist version of it in which the difference between overt and covert movement is whether you spell out the head or the tail of a chain.

By contrast, alternative analyses in terms of unselective binding (Pesetsky 1987 and Watanabe 1992, among others), which certainly account for the presence of scope markers and the island insensitivity displayed by *wh* in situ in languages like Japanese, do not predict Relativized Minimality effects. This is because unselective binding involves a quantifier that binds any and all unbound variables in its scope and therefore a full definite NP in subject position is not expected to intervene in such dependency.

Summarizing, we arrive at the following conclusion. Relativized Minimality effects found in our study suggest that an analysis in terms of covert movement is to be preferred for LSF over an unselective-binding analysis. If Richards 2000 and Bayer & Cheng 2017 are right and the way the covert dependency is established at LF in *wh*-in-situ languages is subject to parameterization, we could go even further in our characterization of LSF: LSF, just like Bengali, shows no evidence for the existence of a scope marker and hence of an unselective binder in *wh* in situ. It is thus reasonable to assume that in *wh* in situ in LSF involves covert movement, as opposed to in *wh* in situ in languages like Japanese, which displays an overt scope marker and involves unselective binding.

Notice that if we are on the right track and LSF belongs to those languages where *wh* in situ involves covert movement, we expect that LSF *wh*-in-situ questions exhibit island sensitivity, like Bengali but in contrast to Japanese. Interestingly, this is exactly what Hauser 2019 has shown. Hauser demonstrates in particular that LSF questions are sensitive to the Coordinate-Structure Constraint and the Complex-NP Constraint (Ross 1967).

With regard to the Coordinate-Structure Constraint, the contrast between (14a) and (14b) on the one hand and (14c) on the other shows that questions in coordinated structures are only possible in LSF when they involve an across-the-board dependency.

- (14) [_{left} JEAN BUY FLOWER] BEFORE [_{right} MARIE STEAL BIKE]. Baseline
 ‘Jean bought flowers and after that Marie stole a bike.’
- a. * [_{left} **WHO** BUY FLOWER] BEFORE [_{right} MARIE STEAL BIKE]? First clause
 ‘*Who bought flowers and after that Marie stole a bike?’
- b. * [_{left} JEAN BUY FLOWER] BEFORE [_{right} **WHO** STEAL BIKE]? Second clause
 ‘*Who Jean bought flowers and after that stole a bike?’
- c. [_{left} **WHO** BUY FLOWER] BEFORE [_{right} __gap STEAL BIKE]? Across the board
 ‘Who bought flowers and after that stole a bike?’

(Hauser 2019: 124–125)

In (14c) the meaning differs from the baseline in that the *wh* word can only be interpreted as corresponding to the subject of both conjuncts.

LSF also displays Complex-NP Constraint effects, in particular with relative clauses. While it is possible to question a main-clause constituent, as (15a) shows, material within the relative clause remains inaccessible to *wh*-question formation, as (15b) illustrates.⁸

- (15) MARIE PREFER WOMAN [_{rel} PI CUDDLE DOG]. Baseline
 ‘Mary prefers the woman who is cuddling the dog.’
- a. **WHO** PREFER WOMAN [(PI) CUDDLE DOG]. Main clause
 ‘Who prefers the woman who is cuddling the dog?’
- b. *IX-2 PREFER WOMAN [(PI) CUDDLE **WHO**]?. Relative clause
 ‘*Who do you prefer the woman who is cuddling?’
- (Hauser 2019: 62)

This pattern contrasts with what happens with sentential complements, where LSF allows questions about constituents of either clause:

- (16) MARIE SAY [WOMAN CUDDLE DOG]. Baseline
 ‘Mary says that the woman is cuddling the dog.’
- a. **WHO** SAY WOMAN [CUDDLE DOG] Main clause
 ‘Who says that the woman is cuddling the dog?’
- b. MARIE SAYS [WOMAN CUDDLE **WHO**]?. Subordinate clause
 ‘Who did Marie say that the woman is cuddling?’
- (Hauser 2019: 62)

In the light of these data, Hauser 2019 concludes that while LSF is a *wh*-in-situ language, it shows the same type of island effects as *wh*-movement languages. This conclusion goes in the same direction as our results on the pattern of comprehension biases observed with *wh*-in-situ questions in LSF. In both cases, the dependency associated with *wh* in situ in LSF presents all the properties of covert movement.

Finally, our results show that age of exposure has a long-lasting impact on the comprehension of *wh* questions, confirming that early language deprivation affects language competence in adulthood. This result joins many others (see Cecchetto et al. 2022, Hauser et al. 2021, Aristodemo et al. 2022, Zorzi et al. 2022) and strongly argues in favor of the implementation of language policies addressed to deaf children that prioritize sign-language exposure as early as possible.

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⁸The gloss PI refers to the LSF relative pronoun identified in Hauser & Geraci 2018. It is a *d*-like relative pronoun (like *der*, *die*, *das* in German and unlike *qui*, *que* in French and *who* in English, which are *wh*-like relative pronouns). It resembles a pointing sign with an extra internal movement added, similar to a flick, and is coarticulated with a mouthing of the sound [pi], hence its gloss.

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Authors’ contributions: All authors conceived and designed the study; CH and VA prepared the experimental materials and implemented the tasks; CH analyzed the data; all authors discussed the results; CD and CH drafted the manuscript; VA revised the first draft. All authors approved the manuscript before submission.

DATA-AVAILABILITY STATEMENT

All the materials, data files, and scripts used for the analysis can be found on the Open Science Framework public repository at <https://osf.io/paj9n/?view&uscore;only=c9eaff3ba5a541cf9829a7de59a82e56>. The assessment tools referenced in section 4 are available upon request via <https://thesignhub.eu/contacts>. The full set of stimuli are listed in the appendix of this article. The data presented in (1)–(4) were collected specifically for this article. Videos can be sent by the corresponding author upon request, for consultation only; they cannot be shared or published elsewhere.

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APPENDIX. LIST OF STIMULI

Fillers

Item code	Gloss and translation
Filler 1	HERE TWO GIRL, ONE MOM. MOM WHERE? 'There are two girls and a mom. Where's the mom?'
Filler 2	IX-1 QUESTION. PUT-CL-HANDLING _(HAT) HAT BLUE WHERE? 'I have a question: where's the blue hat?'
Filler 3	IX-1 QUESTION. BOX WHERE? 'I have a question: where's the box?'
Filler 4	HERE TWO CHILD, ONE CLOWN. CLOWN WHERE? 'There are two children and a clown. Where's the clown?'
Filler 5	IX-1 QUESTION. GIRL BLOND WHERE? 'I have a question: where's the blond girl?'
Filler 6	IX-1 QUESTION. GIRL DRESS BLUE WHERE? 'I have a question: where's the girl in a blue dress?'
Filler 7	HERE TWO BOY, ONE HORSE. HORSE WHERE? 'There are two boys and a horse. Where's the horse?'
Filler 8	HERE TWO GIRL, ONE MOM. GIRL BLOND WHERE? 'There are two girls and a mom. Where's the blond girl?'
Filler 9	IX-1 QUESTION. ELEPHANT GREY WHERE? 'I have a question: where's the grey elephant?'
Filler 10	IX-1 QUESTION. BROOM WHERE? 'I have a question: where's the broom?'
Filler 11	HERE TWO COW, ONE SHEEP. SHEEP WHERE? 'There are two cows and a sheep. Where's the sheep?'
Filler 12	IX-1 QUESTION. TAIL WHERE? 'I have a question: where's the tail?'
Filler 13	HERE TWO CLOWN, ONE CHILD. CHILD WHERE? 'There are two clowns and a child. Where's the child?'
Filler 14	HERE TWO ELEPHANT, ONE LION. LION WHERE? 'There are two elephants and a lion. Where's the lion?'

Block A

Item code	Gloss and translation
Training 1	IX-1 QUESTION. TOWEL RED DARK WHERE? 'I have a question: where is the dark red towel?'
Training 2	IX-1 QUESTION. WHO SPLASH-WATER-WITH-WATER-HOSE CHILD? 'I have a question: who splashes the child (using a water hose)?'
Training 3	HERE TWO ANGEL, ONE MAN. ANGEL WHICH PET MAN? 'There are two angels and a man. Which angel pets the man?'
Wh-04-sbj	IX-1 QUESTION. WHO PUSH MAN? 'I have a question: who pushes the man?'
Wh-05-sbj	IX-1 QUESTION. WHO SPLASH-WATER-WITH-WATER-HOSE LION? 'I have a question: who splashes the lion (using a water hose)?'
Wh-06-obj	IX-1 QUESTION. MAN-DIVER GRAB WHO? 'I have a question: who does the diver grab?'
Wh-07-sbj	IX-1 QUESTION. WHO WIPE CHILD? 'I have a question: who wipes the child?'
Wh-08-sbj	IX-1 QUESTION. WHO PICTURE-TAKE MOM? 'I have a question: who takes a picture of the mom?'
Wh-09-sbj	IX-1 QUESTION. WHO BITE CAT? 'I have a question: who bites the cat?'
Wh-10-sbj	IX-1 QUESTION. WHO CUDDLE CHILD? 'I have a question: who cuddles the child?'
Wh-11-sbj	IX-1 QUESTION. WHO CHEEK-PINCH KING? 'I have a question: who pinches the king's cheek?'
Wh-12-sbj	IX-1 QUESTION. WHO WIPE KING? 'I have a question: who wipes the king?'
Wh-13-obj	IX-1 QUESTION. CHILD PET WHO? 'I have a question: who does the child pet?'
Wh-14-obj	IX-1 QUESTION. COW LICK WHO? 'I have a question: who does the cow lick?'
Wh-15-obj	IX-1 QUESTION. CHILD PUSH-CL-HANDLING _(STROLLER) WHO? 'I have a question: who does the child push in a stroller?'
Wh-16-obj	IX-1 QUESTION. SQUID PUSH WHO? 'I have a question: who does the squid push?'
Wh-17-obj	IX-1 QUESTION. DOG LICK WHO? 'I have a question: who does the dog lick?'

Item code	Gloss and translation
Wh-18-obj	IX-1 QUESTION. DOG LIFT WHO? 'I have a question: who does the dog lift?'
Wh-19-obj	IX-1 QUESTION. FATHER TICKLE WHO? 'I have a question: who does the father tickle?'
Which-20-sbj	HERE TWO LION, ONE CLOWN. LION WHICH SPLASH-WATER-WITH-WATER-HOSE CLOWN? 'There are two lions and a clown. Which lion splashes the clown (using a water hose)?'
Which-21-sbj	HERE TWO SOLDIER, ONE OLD(PERSON). SOLDIER WHICH PAINT PERSON-CL OLD? 'There are two soldiers and an old person. Which soldier paints the old person?'
Which-22-sbj	HERE TWO ANGEL, ONE CHILD. ANGEL WHICH PET CHILD? 'There are two angels and a child. Which angel pets the child?'
Which-23-sbj	HERE TWO PENGUIN, ONE MONKEY. PENGUIN WHICH PUNCH MONKEY? 'There are two penguins and a monkey. Which penguin punches the monkey?'
Which-24-sbj	HERE TWO CHILD, ONE MONKEY. CHILD WHICH PET MONKEY? 'There are two children and a monkey. Which child pets the monkey?'
Which-25-sbj	HERE TWO DANCER, ONE QUEEN. DANCER WHICH GRAB-HANDLING-CL(DRESS) QUEEN? 'There are two dancers and a queen. Which dancer grabs the queen by her dress?'
Which-26-sbj	HERE TWO ZEBRA, ONE COW. ZEBRA WHICH BITE COW? 'There are two zebras and a cow. Which zebra bites the cow?'
Which-27-sbj	HERE TWO DOG, ONE HIPPOPOTAMUS. DOG WHICH PAINT HIPPOPOTAMUS? 'There are two dogs and a hippopotamus. Which dog paints the hippopotamus?'
Which-28-obj	HERE TWO CHILD, ONE FAIRY. FAIRY WATER-PISTOL-SPLASH CHILD WHICH? 'There are two children and a fairy. Which child does the fairy splash (using a water pistol)?'
Which-29-obj	HERE TWO CHILD, ONE MOM. MOM FACE-PAINT CHILD WHICH? 'There are two children and a mom. Which child does the mom paint the face of?'
Which-30-obj	HERE TWO ELEPHANT, ONE CHILD. CHILD PAINT ELEPHANT WHICH? 'There are two elephants and a child. Which elephant does the child paint?'
Which-31-obj	HERE TWO GRANNY, ONE CHILD. CHILD PINCH GRANNY WHICH? 'There are two grannies and a child. Which granny does the child pinch?'
Which-32-obj	HERE TWO CHILD, ONE HIPPOPOTAMUS. HIPPOPOTAMUS WIPE CHILD WHICH? 'There are two children and a hippopotamus. Which child does the hippopotamus wipe?'
Which-33-obj	HERE TWO POLICEMAN, ONE KING. KING BRUSH POLICEMAN WHICH? 'There are two policemen and a king. Which policeman does the king brush?'
Which-34-obj	HERE TWO MAN, ONE MONKEY. MONKEY PICTURE-TAKE MAN WHICH? 'There are two men and a monkey. Which man does the monkey take a picture of?'
Which-35-obj	HERE TWO DOG, ONE CHILD. CHILD PET DOG WHICH? 'There are two dogs and a child. Which dog does the child pet?'

Block B

Item code	Gloss and translation
Training 1	IX-1 QUESTION. TOWEL RED DARK WHERE? 'I have a question: where is the dark red towel?'
Training 2	IX-1 QUESTION. CHILD SPLASH-WATER-WITH-WATER-HOSE WHO? 'I have a question: who does the child splash (using a water hose)?'
Training 3	HERE TWO ANGEL, ONE MAN. MAN PET ANGEL WHICH? 'There are two angels and a man. Which angel does the man pet?'
Wh-04-obj	IX-1 QUESTION. MAN PUSH WHO? 'I have a question: who does the man push?'
Wh-05-obj	IX-1 QUESTION. LION SPLASH-WATER-WITH-WATER-HOSE WHO? 'I have a question: who does the lion splash (using a water hose)?'
Wh-06-sbj	IX-1 QUESTION. WHO GRAB MAN-DIVER? 'I have a question: who grabs the diver?'
Wh-07-obj	IX-1 QUESTION. CHILD WIPE WHO? 'I have a question: who does the child wipe?'
Wh-08-obj	IX-1 QUESTION. MOM PICTURE-TAKE WHO? 'I have a question: who does the mom take a picture of?'
Wh-09-obj	IX-1 QUESTION. CAT BITE WHO? 'I have a question: who does the cat bite?'
Wh-10-obj	IX-1 QUESTION. CHILD CUDDLE WHO? 'I have a question: who does the child cuddle?'
Wh-11-obj	IX-1 QUESTION. KING CHEEK-PINCH WHO? 'I have a question: who does the king pinch the cheek of?'
Wh-12-obj	IX-1 QUESTION. KING WIPE WHO? 'I have a question: who does the king wipe?'
Wh-13-sbj	IX-1 QUESTION. WHO PET CHILD? 'I have a question: who pets the child?'
Wh-14-sbj	IX-1 QUESTION. WHO LICK COW? 'I have a question: who licks the cow?'
Wh-15-sbj	IX-1 QUESTION. WHO PUSH-CL-HANDLING _(STROLLER) CHILD? 'I have a question: who pushes the child in a stroller?'
Wh-16-sbj	IX-1 QUESTION. WHO PUSH SQUID? 'I have a question: who pushes the squid push?'
Wh-17-sbj	IX-1 QUESTION. WHO LICK DOG? 'I have a question: who licks the dog?'

Item code	Gloss and translation
Wh-18-sbj	IX-1 QUESTION. WHO LIFT DOG? 'I have a question: who lifts the dog?'
Wh-19-sbj	IX-1 QUESTION. WHO TICKLE FATHER? 'I have a question: who tickles the father?'
Which-20-obj	HERE TWO LION, ONE CLOWN. CLOWN SPLASH-WATER-WITH-WATER-HOSE LION WHICH? 'There are two lions and a clown. Which lion does the clown splash (using a water hose)?'
Which-21-obj	HERE TWO SOLDIER, ONE OLD (PERSON). PERSON-CL OLD PAINT SOLDIER WHICH? 'There are two soldiers and an old person. Which soldier does the old person paint?'
Which-22-obj	HERE TWO ANGEL, ONE CHILD. CHILD PET ANGEL WHICH? 'There are two angels and a child. Which angel does the child pet?'
Which-23-obj	HERE TWO PENGUIN, ONE MONKEY. MONKEY PUNCH PENGUIN WHICH? 'There are two penguins and a monkey. Which penguin does the monkey punch?'
Which-24-obj	HERE TWO CHILD, ONE MONKEY. MONKEY PET CHILD WHICH? 'There are two children and a monkey. Which child does the monkey pet?'
Which-25-obj	HERE TWO DANCER, ONE QUEEN. QUEEN GRAB-HANDLING-CL _(DRESS) DANCER WHICH? 'There are two dancers and a queen. Which dancer does the queen grab by her dress?'
Which-26-obj	HERE TWO ZEBRA, ONE COW. COW BITE ZEBRA WHICH? 'There are two zebras and a cow. Which zebra does the cow bite?'
Which-27-obj	HERE TWO DOG, ONE HIPPOPOTAMUS. HIPPOPOTAMUS PAINT DOG WHICH? 'There are two dogs and a hippopotamus. Which dog does the hippopotamus paint?'
Which-28-sbj	HERE TWO CHILD, ONE FAIRY. CHILD WHICH WATER-PISTOL-SPLASH FAIRY? 'There are two children and a fairy. Which child splashes the fairy (using a water pistol)?'
Which-29-sbj	HERE TWO CHILD, ONE MOM. CHILD WHICH FACE-PAINT MOM? 'There are two children and a mom. Which child paints the mom's face?'
Which-30-sbj	HERE TWO ELEPHANT, ONE CHILD. ELEPHANT WHICH PAINT CHILD? 'There are two elephants and a child. Which elephant paints the child?'
Which-31-sbj	HERE TWO GRANNY, ONE CHILD. GRANNY WHICH PINCH CHILD? 'There are two grannies and a child. Which granny pinches the child?'
Which-32-sbj	HERE TWO CHILD, ONE HIPPOPOTAMUS. CHILD WHICH WIPE HIPPOPOTAMUS? 'There are two children and a hippopotamus. Which child wipes the hippopotamus?'
Which-33-sbj	HERE TWO POLICEMAN, ONE KING. POLICEMAN WHICH BRUSH KING? 'There are two policemen and a king. Which policeman brushes the king?'
Which-34-sbj	HERE TWO MAN, ONE MONKEY. MAN WHICH PICTURE-TAKE MONKEY? 'There are two men and a monkey. Which man takes a picture of the monkey?'
Which-35-sbj	HERE TWO DOG, ONE CHILD. DOG WHICH PET CHILD? 'There are two dogs and a child. Which dog pets the child?'