**Abstract**

This study investigated the comprehension of *which*-questions among French-speaking monolingual (n=26) and bilingual (n=28) children aged 3 to 12, examining the roles of verbal working memory (WM) and length of exposure to an additional language (L2). We assessed comprehension of subject- and object-questions with a character-selection task, measured verbal WM with a non-word repetition task, and quantified linguistic exposure through a parental questionnaire. Results confirmed the well-known subject-object asymmetry, with object-questions posing greater difficulty than subject-questions for both groups. Additionally, verbal WM significantly impacted comprehension of object-questions among bilinguals, but not monolinguals, with higher WM associated with better performance. Importantly, it was bilinguals with longer exposure to a language other than French who demonstrated improved verbal WM, leading to increased comprehension of object-questions compared to bilingual peers with less L2 exposure. These findings underscore the crucial role of WM in language comprehension and suggest that bilingualism can confer cognitive advantages that in turn enhance complex syntactic processing.

**1. Introduction**

Bilinguals’ exposure to two or more languages has been associated with potential boosts in executive functioning abilities. Executive Functions (EFs) comprise mental skills, which help manage attention to accomplish tasks, such as (a) the ability to temporarily hold in memory verbal information for successful completion of linguistically and cognitively demanding tasks, known as verbal working memory (WM; Just & Carpenter, 1992), and (b) the ability to resist distractions while focusing on a given task, known as inhibition (Bialystok et al., 2004). A body of work has suggested that bilingual children outperform their monolingual peers in tasks that tap into verbal WM (Blom et al., 2014) and tasks that require inhibition of irrelevant information (Miyake et al., 2000). This has been hypothesised to stem from bilinguals’ practice in managing two languages. Specifically, bilinguals must constantly keep two linguistic systems in WM and also need to resolve the competition between their two languages which are active at the same time, thus improving their ability to ignore task-incongruent information (Bialystok, 2010; Bialystok et al., 2004). However, while many previous studies have based their findings on group differences between monolingual and bilingual children (e.g., Blom et al., 2014), less is known about how individual variations in bilingual children’s language experience enhances EF abilities. Moreover, EFs have been claimed to underpin successful comprehension of certain linguistic structures that involve syntactic complexity (Gibson, 1998; Just & Carpenter, 1992). If EFs are boosted by bilingual experience, could this boost in turn enhance successful comprehension of complex structures?

**2. Background**

**2.1. Bilingualism and Cognition**

Bilingualism is a multifaceted phenomenon with no agreed-upon definition (Butler & Hakuta, 2006). For the present purposes, we adopt the definition by Kohnert (2010) who defined bilinguals as those ‘‘individuals who receive regular input in two ... languages during the most dynamic period of communication development — somewhere between birth and adolescence’’ (p. 456). Many studies report that bilinguals display cognitive gains in various EFs, such as attention control (Kharkhurin, 2008), as well as tasks that require resolving interference from competing cues (Adesope et al., 2010; Barac & Bialystok, 2011; Carlson & Meltzoff, 2008). This has been related to their continued practice of devoting attention to the language being used, while suppressing attention to the ‘other’ language. Because of simultaneous activation of both languages, bilinguals constantly monitor which language to use for each communicative interaction (Costa et al., 2009) while inhibiting one of their languages (Jared & Kroll, 2001; Poarch & Van Hell, 2012).

Working memory is another area of EF that has been reportedly enhanced by bilingualism (Monnier et al., 2022). WM refers to the mental processes responsible for the temporary storage and manipulation of information in the face of interference (Baddeley et al., 2009). Because of the nature of information processing in WM, it has been suggested that WM subserves various complex cognitive tasks such as planning, reasoning, and language comprehension (Linck & Weiss, 2011; Martin & Ellis, 2012). Most WM research has been conducted within the tripartite model of Baddeley and colleagues (Baddeley et al., 2009; Baddeley & Hitch, 1974), according to which WM is composed of two slave subsystems responsible for temporary storage of verbal and visuospatial information, respectively. These subsystems are monitored and regulated by a domain-general central executive that is responsible for allocating attention to the two subsystems by inhibiting irrelevant information, shifting mental sets, and updating and monitoring the information currently being processed. Therefore, even though WM is composed of separate subsystems, they constantly interact with each other and are served by the same central executive. Thus, it is reasonable to expect a bilingual advantage to extend to both storage of verbal information and inhibition/cognitive shifting abilities. Interestingly, these have been claimed to be key in successful comprehension of syntactically complex structures which tax WM resources, such as structures involving the fronting of an object in an otherwise S(ubject)-V(erb)-O(bject) language, including object relative clauses (Arosio et al., 2012; Booth et al., 2000) and object *which-*questions (Bentea et al., 2016; Schouwenaars et al., 2018).

**2.2. Comprehension of *which*-questions**

Previous studies have shown that children acquire subject *which-*questions and subject relative clauses at about 3 years old in a variety of languages (O’Grady, 2007, Chapter 7). Indeed, they find subject questions/relative clauses *(1a, b)* easier to comprehend than object questions/relative clauses *(2a,b)*. In *(1a, b)*, *which/the sheep* is interpreted as the subject of *licking*, while in *(2a, b)* itis interpreted as the object.The easier processing of subject as opposed to object gaps is referred to as the subject-object asymmetry and has been observed in studies with adults employing both offline measures such as comprehension accuracy and online measures such as reading time, eye movement, and ERPs (Frazier & D’Arcais, [1989](https://www.tandfonline.com/doi/full/10.1080/02687038.2015.1065469?needAccess=true); Kaan et al., [2000](https://www.tandfonline.com/doi/full/10.1080/02687038.2015.1065469?needAccess=true); Schlesewsky & Bornkessel., [2006](https://www.tandfonline.com/doi/full/10.1080/02687038.2015.1065469?needAccess=true); Stowe, [1986](https://www.tandfonline.com/doi/full/10.1080/02687038.2015.1065469?needAccess=true); Sussman & Sedivy, [2003](https://www.tandfonline.com/doi/full/10.1080/02687038.2015.1065469?needAccess=true)). This asymmetry has also been reported in studies with children conducted with typologically diverse languages, including English (Goodluck, 2005), French (Bentea & Durrleman, 2014), Greek (Stavrakaki, 2006), Hebrew (Friedmann & Novogrodsky, 2011), Italian (De Vincenzi et al., 1999; Guasti et al., 2012), and Romanian (Bentea, 2016).

*(1a) Which sheep \_\_ is licking the duck?* Subject Question

*(1b) The sheep that \_\_ is licking the duck* Subject Relative

*(2a) Which sheep is the duck licking \_\_?* Object Question

*(2b) The sheep that the duck is licking \_\_* Object Relative

Various accounts have explained the subject-object asymmetry but here we focus only on two broad explanations. According to decay-based accounts (Gibson, 1998, 2000), the difficulty with object questions is due to the longer dependency between the surface position of the filler *which/the sheep* and its original position – preverbal in subject gaps and postverbal in object gaps (indicated by an underscore). Such accounts stipulate that the memory representation of fronted elements like *which sheep* in *(1)* and *the sheep* in *(2)* will decay over time and this will disrupt the successful comprehension of structures like *(2a) and (2b)* that involve a longer dependency compared to *(1a) and (1b)*. That active storage of fronted *wh*-phrases is difficult for children has been empirically illustrated by developmental studies of object questions in French (Hamann, 2006; Jakubowicz, 2011): these studies show that children initially produce in-situ object questions (e.g., ‘*Tu as poussé* ***qui****?’* for ‘you pushed **who**?’) before ex-situ object questions (e.g., ‘***Qui*** *tu as poussé?’* for ‘**who** did you push?’). The observation that ex-situ questions appear later in French children’s production data is consistent with the view that WM improves with age, which in turn enhances children’s ability to produce dependencies that span over a greater number of constituents.

A different account attributes the subject-object asymmetry to difficulty in revising an initially preferred subject gap interpretation. According to the *Active Filler Strategy* (Frazier, 1987), the language processor resolves dependencies at the earliest gap site upon identifying the filler, thus assigning all *which-*questions/relatives a subject interpretation as subject gaps appear prior to other structural positions. This suggests that structures such as *(1a, b)* pose less processing costs compared to structures such as *(2a, b)*, since the initial subject interpretation in *(2a, b)* needs to be revised later downstream, whereas no reanalysis is required in *(1a, b).* The initial subject interpretation is demonstrated in a study by Diessel and Tomasello (2005) who showed that when four-year-old children listen to English relative clauses while looking at reversible pictures that correspond to either a subject or object interpretation (picture of a boy chasing a girl vs. picture of a girl chasing a boy) they often select the distractor picture in object relatives (i.e., for *the boy who the girl chased*,the picture selected would represent a boy chasing a girl). This suggests that children face difficulty in revising an initial subject interpretation in object gaps (for similar results, see Arnon, 2010; Brandt et al., 2016).

There are different explanations why subject gap structures should lead to fewer reanalysis errors compared to object gap structures. One possibility is that the presence of an additional NP in object gaps (i.e., *the duck*) disrupts successful dependency formation between the verb (*licking*) and the gap. According to the principle of Relativized Minimality (RM; Rizzi, 1990, 2004; for empirical evidence in children, see Friedmann et al., 2009; Pontikas et al., 2024), the presence of an intervening NP subject (i.e., *the duck*) that is similar in morphosyntactic features with the fronted object *which sheep/the sheep* in *(2a, b)* disrupts the formation of the dependency between the moved element held in working memory and the corresponding gap position: the similarity in morphosyntactic features leads to competition effects, as the intervening subject can act as a potential candidate for the filler in the syntactic relation established between the fronted constituent and the gap. Consistent with RM, Bentea and Durrleman (2017) demonstrated in a character-selection task that French-speaking children aged 6 to 8 find object relatives significantly easier when there is a number mismatch between the NPs in the dependency (e.g., *the ant*[SG] *that the* ladybugs[PL] *are following*) compared to when there is not (e.g., *the ant*[SG] *that the ladybug*[SG] *is following*). The effect of number mismatch has also been observed in Italian relative clauses (Adani et al., 2010), as well as for *which*-questions in English, both in monolingual (Contemori et al., 2018) and in bilingual children (Pontikas et al., 2024).

Another potential explanation for the increased difficulty in revising an initial subject interpretation in object questions is the additional level of perspective shifting required for successful comprehension of object gaps (MacWhinney, 1977, 1982). According to the perspective shifting view, fronted elements and syntactic subjects map onto listeners’ current perspective of an agent-first structure, and language comprehension is easier when this perspective in memory is maintained, as in subject questions, than when this perspective needs to be updated, as in object questions. In subject gaps *(1a, b)*, the fronted *which/the sheep* is also the subject of *licking* and thus no perspective shifting is required. By contrast, in object questions *(2a, b)*, *which/the sheep* is not the subject of *licking*, and when the subject *the duck* is processed, a shifting in perspective is required from *which/the sheep* to *the duck* and then back to *which/the sheep*.

Overall, previous research has indicated that object gaps present more comprehension difficulty than subject gaps, which stems from cognitive limitations in storing verbal information in WM and revising an initially preferred subject interpretation. While the cognitive resources involved in the revision of a subject interpretation differ depending on an RM or perspective-shifting view (with RM relying on WM coupled with inhibition and perspective shifting on WM coupled with updating/shifting), they both account for specific difficulty with (ex-situ) object questions yielding their increased misanalysis and avoidance. The present study does not aim to tease apart these two views, but rather to explore how bilingualism, which can impact EFs, can in turn influence the interpretation of these structures that solicit revision of a representation held in WM according to both accounts.

**3. Present Study**

Against this background, we investigate the comprehension of subject and object *which-*questions by 3-to-12-year-old monolingual and bilingual children with French as their native language (L1). The aim is to examine potential links between performance on these *wh*-questions and their verbal WM, and how this would be influenced by experience with a second language (L2). Specifically, we hypothesise that if there is a bilingual advantage in the storage of verbal information and revision of an initial subject gap interpretation, we expect to observe higher comprehension accuracy in bilinguals as a function of verbal WM and fewer misanalysis errors, which would be mediated by bilingual experience. Longer exposure to an additional language among bilingual children should enhance their verbal WM and thus increase accuracy in revising an initially misanalysed object *which*-question as a subject *which*-question. With this in mind, the research questions (RQs) were as follows:

(RQ1) Are there differences between monolingual and bilingual children in the comprehension of subject and object *which*-questions in French?

To answer (*RQ1*), we compare accuracy in subject and object questions between monolingual and bilingual children and explore the effect of age. Following previous studies, we expect to find a subject-object asymmetry, such that both groups should find object questions more difficult to comprehend than subject questions. Regarding monolingual-bilingual differences, it is expected that since bilinguals receive overall less input in their L1, French, compared to their monolingual peers, they might show less accuracy on the more difficult object questions.

Furthermore, we examine error patterns to assess to what extent monolingual and bilingual children misinterpret object questions as subject questions rather than misinterpret subject questions as object questions. Following Diessel and Tomasello (2005), we operationalise this in terms of comprehension errors in object vs. subject questions.

*(RQ2)* How does verbal WM impact comprehension of subject and object questions among monolingual and bilingual children?

We investigate how individual differences in verbal WM impact comprehension of subject and object questions. We expect that verbal WM will be solicited more strongly in object than subject questions, as the displaced *which*-phrase needs to be stored in WM over a longer dependency distance in object questions, as predicted under various accounts. On the contrary, we expect error patterns to reflect WM limitations in children, in that children with low WM should favour the most currently processed constituent as the filler, resulting in a larger rate of misanalysis of object vs. subject questions, while those with high WM should have less difficulty searching between distracting NPs for the filler.

*(RQ3)* To what extent does length of exposure to languages other than French mediate the relationship between verbal WM and comprehension accuracy?

To answer *(RQ3)*, we focus on the bilingual group and examine potential links between length of exposure to an additional language on comprehension accuracy in French subject and object questions. We hypothesised that a potential relationship between verbal WM and comprehension accuracy in object questions as investigated in *(RQ2)* should be mediated by bilingual children’s previous linguistic experiences. Specifically, we expect children with longer exposure to an additional language to have higher verbal WM (after controlling for age), as they would have more experience in dual language management, which in turn should lead to higher comprehension accuracy on object questions compared to their peers with less exposure to an L2 and correspondingly less WM.

**3.1. Method**

**3.1. Participants**

Data for this study came from 26 monolingual and 25 bilingual French-speaking children (mean age in years = 7.63, range: [3.42, 11.50]), recruited in Switzerland and France. Prior to the experiment, the parents of participating children or other legally authorised caregivers signed a consent form. Parents also completed a language history Q-BEx questionnaire (De Cat et al., 2022) and indicated that either their children’s most dominant language was French, or that their children spoke French as an additional language, while French was not their most proficient language. The first language (L1) was defined as the language that the child was most proficient in, as assessed by Q-Bex (see below), while the second language (L2) was the second most proficient language. Following Cantone (2022) and Hantman et al. (2023), we distinguished between monolingual and bilingual children by referring to bilinguals as those children whose parents identified their cumulative exposure to an L2 to be more than 20%. While some parents specified that their children were also exposed to a third language (L3), as illustrated in Figure 1, the bilingual vs. monolingual classification does not suggest that so-called monolinguals were not exposed to an L2. That is, some monolingual children were also exposed to additional languages, but their cumulative exposure was below the cutoff 20%. As can be seen in Table 1, bilinguals’ proficiency in their L2 was higher than monolinguals’ proficiency in their L2 and bilingual children were exposed to an L2 earlier than their monolingual peers.

Besides other background variables, we also measured composite scores on the richness of exposure to different languages, which varied based on the frequency with which children engaged in daily activities using different languages (e.g., doing homework, receiving lessons at school, using technology) as well as proficiency in those languages (parents rated how well their children’s proficiency was in each language compared to their same age peers).



**Figure 1.** Distribution of bilingual participants' additional languages (L2 or L3).

**Table 1.** Information on participants’ demographics and linguistic background

|  |  |
| --- | --- |
|  | **Group** |
| **Bilingual(N=28)** | **Monolingual(N=26)** | **Total****(N = 54)** |
| **Biological Gender** |  |  |  |
| Male | 17 (51%) | 15 (58%) | 32 (59%) |
| Female | 11 (39%) | 11 (42%) | 22 (41%) |
| **Age (months)** |  |  |  |
| Mean (SD) | 99 (24) | 83 (24) | 92 (25) |
| Median [Min, Max] | 102 [63, 138] | 80 [41, 133] | 89 [41, 138] |
| **Richness of exposure to French****(**min: 0, max: 1) |  |  |  |
| Mean (SD) | .600 (.183) | .622 (.162) | .609 (.173) |
| Median [Min, Max] | .545 [.295, .886] | .659 [.295, .886] | .614 [.295, .886] |
| **Proficiency in French****(**min: 0, max: 1) |  |  |  |
| Mean (SD) | .651 (.238) | .765 (.256) | .716 (.252) |
| Median [Min, Max] | .500 [.167, 1.000] | .875 [.250, 1.000] | .750 [.167, 1.000] |
| **Age of first exposure to L2 (months)** |  |  |  |
| Mean (SD) | 9 (16) | 24 (27) | 15 (22) |
| Median [Min, Max] | 0.5 [0, 54] | 12 [0, 85] | 1 [0, 85] |
| **Richness of exposure to L2****(**min: 0, max: 1) |  |  |  |
| Mean (SD) | .390 (.167) | .325 (.148) | .364 (.161) |
| Median [Min, Max] | .364 [.046, .780] | .318 [.114, .591] | .341 [.046, .795] |
| **Proficiency in L2****(**min: 0, max: 1) |  |  |  |
| Mean (SD) | .565 (.247) | .307 (.242) | .461 (.274) |
| Median [Min, Max] | .583 [.0833, 1.000] | .250 [0, .833] | .500 [0, 1.000] |

**3.2. Linguistic background variables and verbal WM**

**3.2.1. QBEX**

We used the Q-BEx parental questionnaire (De Cat et al., 2022) to collect data on children's language experiences. Q-BEx comprises a series of modules to collect biographic information and assess the length and richness of exposure to additional languages as well as proficiency in these languages. In this study, we focused on data from ‘background information’, ‘language exposure and use’, ‘proficiency’, and ‘richness’ modules.

**3.2.2. Verbal WM: Nonword Repetition Task**

Verbal WM was assessed through a nonword-repetition (NWR) task from the LITMUS test battery (Hamdani et al., 2024). Participating children were required to repeat 16 nonsense words that do not exist in any language, which varied in syllable length from 2 to 5. Verbal WM was calculated as the total number of correctly repeated nonwords (maximum score: 16).

**3.3. Gamified Syntactic Comprehension Task**

This task tested the comprehension of a variety of syntactic structures via a gamified App on a tablet (iPad). The app was designed to assess language comprehension in young children and children with linguistic and cognitive impairments, and thus avoided unnecessary visual and verbal details. Comprehension of subject and object questions was assessed on 12 items overall (6 subject, 6 object), interspersed with 48 other structures of different levels of syntactic complexity which served as fillers for the purpose of the current study[[1]](#footnote-1). Following a familiarisation phase, the items were randomised. Vocabulary was designed with reference to French language norms for words expected for children aged 3-6 years (MacArthur Bates CDI2). The experimenter always sat with each child during the game and pauses were provided as needed.

Comprehension of subject and object questions was tested using a character selection task in which children saw an image on the screen while hearing a subject or object question. They then had to touch the character identified by the question. This meant choosing only one among three characters that were involved in the same action (Figure 2). The items selected and the procedure were inspired by psycholinguistic work targeting the relevant constructions (e.g., Durrleman & Bentea, 2021; Friedmann et al., 2009). All the items maintained the same format, as below:

a) familiarisation with the main characters involved in the target structure (e.g. *Waouh, un canard et deux moutons* for ‘Wow, a duck and two sheep!’);

b) aural presentation of the test item while looking at the image on the screen;

c) each image contained three possible response options. The characters on the left and right always referred to the fronted which-phrase and were either the agent or patient of the depicted action; thus, one of these characters was represented in the accurate agent-patient distribution, while the other in the reversed theta-role distribution. The character in the middle was always the referent of the other noun in the question; since this noun was never associated with the target answer, we classified this response option as oddball, also referred to as the embedded NP error in previous work (Arnon, 2010, Adani et al., 2010);

d) once the child pointed to a character, they received an encouraging comment from the experimenter (e.g., *Fantastique!* ‘fantastic’, Bien joué! ‘good game’, etc.)

Example 3 illustrates a test item.



**Figure 2**. Example of image associated with a test item.

3a. *Waouh, un canard et deux moutons!*

‘Wow, a duck and two sheep!’

3b. *Quel mouton lèche le canard? Montre-moi.* Subject Question

 which-sheep lick the.M.SG duck? Show me.

 ‘Which sheep is licking the duck?’

3b. *Quel mouton le canard lèche-t-il? Montre-moi.* Object Question

 which-sheep the.M.SG duck lick? Show me.

 ‘Which sheep is the duck licking?’

**3.4. Procedure**

Children were tested over the course of two sessions to avoid fatigue, in a quiet environment with an experimenter present to assist them through the tasks. Tests were conducted in French, which was also the language typically acquired before the age of 3. Alongside the newly devised Syntactic Comprehension Task (see below), children also completed a nonword repetition task to allow the exploration of potential links between comprehension and WM. Finally, parents completed the QBex questionnaire, to provide information about their children’s linguistic experiences. The study was approved by the Swiss Association of Research Ethics Committees, Swissethics (Project-ID 2022-00878) and parents signed consent forms allowing their children to participate.

**3.5. Data Analysis**

For statistical analysis, different sets of (generalised) linear mixed effect models were created in R (R Core Team, 2020) with random effects for participants and items. All models were fitted using the *lme4* package with a logit link function (Bates et al., 2015). We created two sets of models to examine accuracy and error types. For the first set of models, response accuracy was the binary dependent variable (accurate, inaccurate), while error type (oddball, reversed) was the dependent variable for the second set of models. All models included sum-coded (+.5, -.5) fixed effects of question type (subject, object), group (monolingual, bilingual), and their interaction; chronological age, verbal WM, length of L2 exposure, and proficiency scores in French, were scaled and entered as covariates.[[2]](#footnote-2) When by-group interactions were significant, we created additional models for monolingual and bilingual children, separately, to locate the source of these interactions (for full details on the results of statistical analysis, see OSF page[[3]](#footnote-3)).

**4. Results**

Figure 3 shows the overall accuracy in subject and object questions for monolingual (object: mean = 61%, SD = 49; subject = 89%, SD = 31) and bilingual children (object: mean = 54%, SD = 50; subject = 91%, SD = 29), while Figure 4 illustrates the percentage of reversal errors for monolinguals (object: mean = 70%, SD = 46; subject = 41%, SD = 51) and bilinguals (object: mean = 74%, SD = 44; subject = 41%, SD = 51). Descriptively, bilinguals performed worse on comprehension of object questions (Figure 4), which is also illustrated by higher number of reversal errors by bilingual children in object questions, compared to monolinguals.



**Figure 3.** Accuracy in object and subject questions by monolingual and bilingual groups



**Figure 4.** Percentage of reversal errors in object and subject questions by monolingual and bilingual groups

**4.1. Comprehension accuracy and error patterns as a function of age (RQ1)**

Initially, we created two binomial models on accuracy (accurate, inaccurate) and error type (oddball, reversal) to compare monolingual and bilingual children in overall accuracy and inclination towards reversal errors. The fixed effects were group (monolingual, bilingual), question type (subject, object), age, and their interaction. The results are presented in Table 2.

**Table 2.** Results of models for accuracy and error type as a function of question type (subject, object), group (monolingual, bilingual), and age

|  |  |  |  |
| --- | --- | --- | --- |
|  | Accuracy (incorrect, correct) |  | Error (oddball vs. reversal) |
| *Predictors* | *Estimate* | *SE* | *z* | *p* |  | *Estimate* | *SE* | *z* | *p* |
| Intercept | 1.777 | .274 | 6.491 | **<.001** |  | .253 | .311 | .815 | .415 |
| Question type (object vs. subject) | -2.575 | .316 | -8.151 | **<.001** |  | 1.564 | .545 | 2.868 | **.004** |
| Group (bilingual vs. monolingual) | -.639 | .520 | -1.227 | .220 |  | .227 | .560 | .405 | .685 |
| Age | .818 | .261 | 3.140 | **.002** |  | -.078 | .258 | -.303 | .762 |
| Question type × Group | -1.272 | .605 | -2.103 | **.035** |  | -.020 | 1.064 | -.019 | .985 |
| Question type × Age | .848 | .287 | 2.959 | **.003** |  | .056 | .499 | .112 | .911 |
| Group × Age | -.208 | .513 | -.406 | .685 |  | .646 | .521 | 1.239 | .215 |
| Question type × Group × Age | .674 | .572 | 1.178 | .239 |  | -1.785 | 1.011 | -1.766 | .077 |

*Note.* Model formula in R: accuracy or Error ~ question type\*group\*scaled(age)+ (1|subject) + (1|item)

As for accuracy, the results indicated that object questions were more difficult than subject questions, consistent with previous studies showing a subject-object asymmetry. Both the main effect of age and its interaction with question type were significant. Follow-up models showed that accuracy on questions improved more steeply for object than subject questions, hence the interaction. (Figure 5).



**Figure 5.** Predicted probabilities showing the effect of age on bilingual and monolingual children's comprehension of subject and object questions

The main effect of group was not significant, but there was a significant interaction between group and question type. Follow-up analyses revealed that while both monolinguals and bilinguals showed higher accuracy on subject questions than on object questions, bilinguals had a greater difficulty with object questions relative to subject questions (estimate = 2.916, SE = .432, *z* = 6.749, *p* < .001) compared to monolinguals (estimate = 2.064, SE = .386, *z* = 5.348, *p* < .001). This finding confirms the observation in Figure 3, where bilinguals demonstrate lower comprehension accuracy on object questions than monolinguals. Additionally, the three-way interaction between group, age, and question type was not significant, indicating that accuracy improved with age similarly in both groups.

Regarding error patterns, reversal errors were more frequent in object than subject questions, suggesting that children were more likely to misanalyse object questions as subject questions than to misanalyse subject questions as object questions. No other effects were significant. Therefore, the results for RQ1 confirmed the widely observed subject-object asymmetry and suggested that bilinguals had additional difficulty with object questions compared to monolinguals, although both groups demonstrated improved accuracy with age.

**4.2. Individual differences in verbal working memory (RQ2)**

In the next step, we added the effect of verbal WM, as well as its interactions with group (monolingual, bilingual) and question type (subject, object) to assess individual differences in monolingual and bilingual children’s comprehension of subject and object questions. We also included the interaction between verbal WM and age to control for the impact of WM that is due to age differences. Table 3 presents the results for predictors that included verbal WM.

**Table 3.** Results of models on accuracy and error type as a function of individual differences in verbal WM

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Accuracy (incorrect, correct)** |  | **Error (oddball, reversal)** |
| *Predictors* | *Estimate* | *SE* | *z* | *p* |  | *Estimate* | *SE* | *z* | *p* |
| Verbal WM | .485 | .165 | 2.939 | **.003** |  | .043 | .554 | .077 | .939 |
| Group × Verbal WM | -.851 | .522 | -1.629 | .103 |  | -.494 | 1.158 | -.426 | .670 |
| Question type × Verbal WM | .362 | .294 | 1.230 | .219 |  | -.079 | 1.047 | -.076 | .940 |
| Verbal WM × Age | .195 | .148 | 1.317 | .188 |  | .317 | .361 | .879 | .380 |
| Question type × Group× Verbal WM | 1.417 | .580 | 2.441 | **.015** |  | -.883 | 2.035 | -.434 | .664 |

*Note.* Model formula in R: accuracy or Error ~ question type\*group\*scaled(verbal WM) + scaled (verbal WM)\*scaled(age) + (1|subject) + (1|item). The Table only shows predictors that include verbal WM; for other predictors, refer to Table 2).

The results showed a significant main effect of verbal WM, with higher accuracy among children with higher verbal WM. In addition, there was a significant three-way interaction between group, verbal WM, and question type. Follow-up analyses showed that improved verbal WM did not significantly affect accuracy on subject questions for either monolinguals (estimate = .513, SE = .763, *z* =.673, *p* = .501) or bilinguals (estimate = 2.313, SE = 1.296, *z* = 1.785, *p* = .074). However, while improved verbal WM did not significantly impact accuracy on object questions for monolinguals (estimate =.005, SE = .182, *z* = .025, *p* = .980), bilingual accuracy on object questions significantly improved by enhanced verbal WM (estimate = .942, SE = .451, *z* = 2.087, *p* = .037). No other effects were significant. Therefore, verbal WM was more strongly solicited among bilinguals than monolinguals for object questions, whereas accuracy remained high in subject questions for both groups regardless of individual differences in verbal WM.

To summarise, the results for RQ1 and RQ2 indicated that object questions were more difficult than subject questions for both monolinguals and bilinguals, with accuracy improving among older children and among children with higher WM. Additionally, while bilinguals found object questions more difficult than monolinguals did, their accuracy on object questions improved with enhanced verbal WM. To further explore the role of verbal WM in bilingual children, we next examine how the effect of verbal WM on accuracy among bilingual children relates to their length of exposure to an additional language (RQ3).

**4.3. Mediating effect of length of exposure to an additional language (RQ3)**

To assess whether length of exposure to a language other than French among bilingual children leads to boosts in verbal WM which in turn enhances comprehension of object questions, we carried out causal mediation analysis using the *mediation* package (Tingley et al., 2014). First, we created a linear model to predict verbal WM as a function of age and length of exposure to an additional language. The effect of age on verbal WM was significant among bilingual children, with better WM among older bilingual children (estimate = .031, SE = .007, *t* = 4.159, *p* < .001), and verbal WM was higher among those bilinguals with longer exposure to an additional language compared to those with more limited exposure (estimate = .039, SE = .007, *t* = 4.159, *p* < .001). This suggests that exposure to an additional language was associated with a boost in verbal WM after controlling for age.

Next, we examined the extent to which the effect of verbal WM on accuracy for object questions reported in (RQ2) can be explained by differences in longer e.xposure to an additional language. This allowed us to examine the indirect effect of length of exposure on accuracy, an effect that mediates the effect of verbal WM on accuracy on object questions. The results showed a significant mediating effect through WM of length of exposure to an additional language (proportion of mediation: .124, *p* = .008), indicating an indirect effect of 12%. This suggests that longer exposure to a language other than French enhances bilingual children’s verbal WM, which in turn boosts their comprehension of object questions in French.

**5. Discussion**

In the current study, we investigated comprehension of *which*-questions in French-speaking 3-to-12-year-old children. We used monolingual vs bilingual comparisons, as well as within-bilingual-group analyses to explore the role that WM and length of L2 exposure play in shaping children’s comprehension of complex syntactic structures such as *which*-dependencies. We hypothesised that object questions should be more difficult than subject questions across both groups, as demonstrated by many previous studies, but this difficulty should be moderated by verbal WM, as argued by decay-based accounts (Gibson, 1998, 2000). We also hypothesised that bilingual children’s exposure to an additional language other than French should lead to improved verbal WM, which should enhance comprehension of object vs. subject questions.

More specifically, we asked three RQs to assess the factors that lead to improved comprehension of subject vs. object questions among monolingual and bilingual children. The first research question was whether differences emerge between monolingual and bilingual children in the comprehension of subject and object *which*-questions in French. The results of the character-selection task showed that monolingual and bilingual children struggle more with the comprehension of object than subject questions. This is in line with previous cross-linguistic findings reporting a subject-object asymmetry in *which*-questions in monolingual and bilingual children (Bentea, 2016; Bentea et al., 2016; Contemori et al., 2018; Durrleman et al., 2016; Friedmann et al., 2009, 2017; Pontikas et al., 2023; Roesch & Chondrogianni, 2016; Schouwenaars et al., 2018). However, we also found higher accuracy on object relative to subject questions for monolinguals compared to bilinguals. We note that while bilingual children were on average 9 months older, monolingual children were overall more proficient in French than their bilingual peers (see Table 1). Additionally, length of exposure to French was lower among bilingual (mean = 52 months, SD = 24) than monolingual children (mean = 73, SD = 29), and therefore, it is possible that due to overall larger amounts of French input received, monolingual children had more experience with object questions, leading to improved comprehension accuracy among monolinguals compared to bilinguals. This was confirmed by another model that we created to examine the impact of French proficiency on accuracy on subject and object questions (formula in R: accuracy ~ question type\*scaled (proficiency)), indicating a significant main effect of proficiency (estimate = 1.184, SE = .242, *z* = 4.895, *p* < .001). No other effects were significant, supporting the conclusion that improved proficiency in French enhances comprehension accuracy in both subject and object questions.

These results were similar to those in Roesch and Chondrogianni (2016) who observed that French-German bilingual children aged 4 to 5 were outperformed by German monolinguals in a comprehension task, but differed from those reported for the comprehension of *which*-questions in English bilinguals aged 7 to 11 (Pontikas et al., 2023) who found no difference between monolingual and bilingual children. The difference in results between the present study and Pontikas et al.’s (2023) study, on the one hand, and Roesch and Chondrogianni’s (2016) study, on the other, could be attributed to the larger age range included in the present study. This is further corroborated by the effect of age that emerged in our study, suggesting that comprehension of object questions significantly improves with age in both monolinguals and bilinguals.

However, we note that while Roesch and Chondrogianni (2016) controlled for language combination, our participants, like in Pontikas et al.’s (2023) study came from a variety of linguistic backgrounds, which could not preclude potential effects of cross-linguistic influence. While we cannot make a strong case for these effects on the comprehension of *which*-questions, further studies could shed light on this by looking into specific language combinations. We also note that the manipulation in Roesch & Chondrogianni (2016) targeted different types of case markings, which was not the case in this study. Similarly, the manipulation in Pontikas et al. (2023) involved different number markings on the filler and the distracting noun, which was not the targeted feature in this work either. Thus, we remain cautious in making any direct comparisons between our results on the one hand, and those of Roesch and Chondrogianni (2016) and Pontikas et al. (2023), on the other.

The analysis of error patterns revealed that children made more reversal errors in object questions than in subject questions. Their error pattern indicated that they interpreted the fronted *wh*-phrase as the agent of the action expressed by the verb and linked it to the subject gap even when the moved *wh*-element should have been interpreted as the patient of the action and linked to the object gap. This type of error can be taken as evidence that children start off with an agent-first interpretation which they subsequently need to revise based on the incoming linguistic information. The fact that children have more difficulties with object questions and make more reversal errors in object compared to subject questions suggests that they find reanalysis difficult. This is in line with previous studies with children showing that once they have committed to an initial interpretation, children struggle to revise it when they encounter information that arrives later in the structure (Omaki et al., 2014; Omaki & Lidz, 2015; Pozzan & Trueswell, 2015; Roesch & Chondrogianni, 20116; Trueswell et al., 1999).

We note that the three-way interaction between question type, group, and age was marginally significant, as shown in Table 1. Although we cannot draw a strong conclusion as this was not statistically significant at p < .05 level, this interaction indicates that older bilingual children make (numerically) fewer reversal errors in object than subject questions, compared to monolinguals. This suggests that children’s ability to discard an initial misanalysis improves during middle childhood (Weighall, 2008), a developmental period also marked by significant advancements in cognitive control (Novick et al., 2005).

Regarding the second research question, namely to what extent verbal WM impacts comprehension of subject and object questions, the findings showed that verbal WM influences the comprehension of object (relative to subject) questions in bilingual children, while comprehension of object questions was not impacted by verbal WM among monolinguals. The impact of verbal WM among bilingual children aligns with previous research as studies have found that children with higher WM capacity show better comprehension of object gaps like *which*-questions (Schouwenaars et al., 2018) and relative clauses (Arosio et al., 2012; Bentea et al., 2016; Booth et al., 2000). Recall that object questions involve a longer dependency distance compared to subject questions, and therefore, successful comprehension of object questions requires processing a greater number of constituents prior to the verb. This finding further supports the hypothesis that the increased difficulty with reanalysis in child comprehension is linked to developmental limitations in WM and potentially more globally in executive functions. These limitations in computational resources force children to commit to a single analysis and hinder their ability to reanalyse a complex structure (Trueswell et al., 1999). The difference in WM effects between monolingual and bilingual children is interesting, as it suggests that WM is more strongly solicited for bilingual children, potentially to compensate for less exposure to French.

To further explore the impact of verbal WM in bilingual children, we asked in our final research question to what extent improved comprehension in bilingual children with higher verbal WM can be attributed to their experience in processing languages other than French. We found that verbal WM was overall higher among those bilinguals that had longer experience with dual language management, operationalised in this study as longer L2 exposure. Those children who were exposed to an additional language for a longer period had higher verbal WM compared to their peers with more limited exposure to an additional language. These results were obtained after controlling for the effect of age in monolingual and bilingual children, and therefore are consistent with previous studies demonstrating that bilingual children’s experience with dual language management leads to cognitive benefits, in particular enhancements in verbal WM (Blom et al., 2014).

Importantly, we also showed that the WM advantage due to length of exposure to an additional language led to improved comprehension of object questions in French. This might seem counterintuitive, in that those children who receive more exposure to a language other than French will inevitably have less exposure to French, which might lead to deteriorated comprehension of French object questions. However, we found a significant indirect effect of length of exposure to an additional language among bilingual children, an effect that mediated the effect of verbal WM on accuracy for object questions. Specifically, longer exposure to a language other than French leads to improved verbal WM, which in turn enhances comprehension of object questions in French.

It should be noted that we did not have a direct measure of inhibition or shifting/updating, and therefore the cognitive underpinnings of the observed bilingual advantage due to longer L2 exposure remain to be explored. That is, while we found better performance on object questions among bilinguals with longer L2 exposure, we do not draw a strong conclusion as to the underlying cognitive resources invoked. Instead, our results highlight that exposure to an additional language is associated with boosts in WM capacity to hold verbal information, which enhances comprehension of syntactically complex structures such as object questions.

**6. Conclusion**

The present study investigated the comprehension of *which*-questions in French-speaking monolingual and bilingual children aged 3 to 12 years, focusing on the roles of verbal WM and length of L2 exposure. We posed three research questions to examine the factors influencing the comprehension of subject versus object questions among these children. Our findings confirmed that object questions are more challenging than subject questions for both monolingual and bilingual children, aligning with previous studies on the subject-object asymmetry. Notably, object questions were additionally difficult for bilingual children, likely due to receiving less input in French and thus lower French proficiency.

Our analysis revealed that verbal WM significantly impacts the comprehension of object questions in bilingual children, with higher verbal WM correlating with better comprehension. Interestingly, despite having less exposure to French than monolinguals, bilingual children demonstrated enhanced accuracy as a result of longer exposure to an L2 which was associated with boosts in verbal WM. Therefore, our results showed that longer exposure to a language other than French improves verbal WM, which enhances comprehension of *which*-questions in French as well. These results underscore the importance of WM in child language comprehension and suggest that bilingual experience can enhance cognitive control, contributing to improved comprehension of complex syntactic structures. Further research should continue to explore the interplay between bilingualism, WM, and language comprehension to deepen our understanding of these dynamics.

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1. This experiment was part of a larger test battery, and the target structures were simple (n = 6) and complement clauses (n = 6), active (n = 6) and passive (n = 6) voice structures, subject (n = 6) and object (n = 6) relative clauses, and sentences involving direct (n = 6) and indirect (n = 6) reported speech. [↑](#footnote-ref-1)
2. Models for each covariate were fitted separately to avoid issues related to multicollinearity and overparameterisation which may mask the effects of interest. Nevertheless, multicollinearity was checked after each model by inspecting the variance inflation factor (VIF) associated with each model term (VIFs in all models <5). [↑](#footnote-ref-2)
3. <https://osf.io/xatyn/?view_only=25ece593e24d427499b1f513fb3a72db> [↑](#footnote-ref-3)