Revisiting Agreement: Do Children and Adults Compute Subject-verb Agreement Differently?

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Abstract

Adult speakers rarely produce a verb that does not agree with its subject in number, unless the sentence contains nouns with clashing pluralities. For example, a sentence such as "The key next to the cabinets…", sometimes elicits a plural verb, and such *attraction errors* are more common with singular than plural heads (*the attraction asymmetry*). Both attraction and attraction asymmetry have been instrumental in understanding the computations underlying agreement production. Interestingly, developmental studies of agreement have often found very different patterns of agreement errors in children, leading to the conclusion of different mechanisms for agreement production in children and adults. Using a referential communication game, we demonstrate that English-speaking children as young as 5 years of age show robust agreement attraction. Children 6 years and older also demonstrate the attraction asymmetry. These findings support similar mechanisms underlying agreement production in children and adults.

Keywords: subject-verb agreement; language production; children; agreement attraction

Introduction

In English, as well as many other languages, sentence verbs must agree with their subjects in number. Consequently, computing subject-verb agreement is one of the most well-practiced syntactic operations in sentence production. While native adult speakers produce the correct agreement frequently and effortlessly, certain circumstances elicit agreement errors. Such errors are usually observed when two nouns in the sentence have different pluralities. For example, "The key next to the cabinets…" sometimes elicits the verb "are" which agrees with the local noun instead of the subject. These so-called *attraction errors* are more common in SP (singular head noun and plural local noun) than PS (plural head noun and singular local noun) sentences, a phenomenon that is called the *asymmetry of attraction* (Bock & Miller, 1991).

Both attraction and its asymmetry have informed the mechanisms of subject-verb computation in adult speakers (see below). The comparison between the pattern of such errors in adults and children has also been used to test whether agreement computations in children do or do not follow the same computational principles as adult speakers. To date, the data from children have suggested that they do not. However, most such studies have either used French-speaking populations (in which plural morphology is often silent in spoken production), and/or tasks that required orthographic knowledge or imposed high demands on working memory (Fayol et al., 1999; Franck et al., 2004). Using a referential communication game that removes such demands, and the English language, which provides reliable singular-plural cues on nouns and verbs, we revisit the question: Do children and adults show similar patterns of agreement errors for verbs "is" and "are"?

Account of agreement attraction in adult speakers

While the goal of this study is not to test a specific model of agreement attraction, a brief review of the models is necessary in order to understand what attraction and attraction asymmetry can tell us about mechanisms of agreement production. Generally speaking, two classes of models have been proposed: *representational* accounts and *processing* accounts. Representational accounts emphasize the nature of the linguistic representations that take part in agreement computations. For example, the Percolation account (e.g., Franck et al., 2002) describes attraction as the number feature percolating up from the local noun to the noun phrase (NP) root level. This group of accounts also contains Continuous Valuation models, which view the representation of the subject noun's number as continuous. A computational implementation of this view is the Marking and Morphing model (Eberhard et al., 2005), which uses the notional number of the head noun, as well as the morphological number information on the head noun and the local noun, to pick the correct verb. When a singular-subject sentence contains a plural local noun, a non-zero value for the plural morpheme activates the plural verb, which increases the probability of attraction. The singular is the default or unmarked state (with the value of 0). Thus, while a plural local noun activates the plural verb, a singular local noun

does not contribute to the activation of a singular verb, creating the attraction asymmetry.

Processing models of agreement, on the other hand, are mostly focused on the cognitive processes, such as memory and control processes, involved in agreement computations, and view attraction as a consequence of resource limitations in such processes (e.g., Engelmann et al., 2019). For example, Badecker and Kuminiak (2007) posit that selecting the correct verb form requires reactivating the relevant noun from memory. This process of reactivation can be faulty when the target content, i.e., the subject noun, partially overlaps with similar but irrelevant content, i.e., a local noun. Reactivation of the wrong content can thus elicit the incorrect verb form and create agreement attraction.

Recently, Nozari and Omaki (2018; 2022) proposed a hybrid model that combined the assumptions of the Continuous Valuation models with the resource limitations proposed by the processing models. According to this account, different cues (e.g., singular vs. plural markers on head and local nouns) activate conflicting representations (e.g., plural vs. singular verb forms) that compete for selection. Such conflict, if not resolved, leads to agreement errors. In most cases, however, conflict triggers monitoring and control mechanisms that intervene to successfully resolve conflict in favor of the correct response, unless such processes are taxed. To test this view, they had participants play an interactive game with the experimenter by instructing her how to color animals on her screen. Participants saw slides that contained groups of colored animals (Fig. 1) and learned that the experimenter had sheets with identical compositions, only with some animals in black and white. The experimenter pointed out the contrast sets (e.g., birds of different colors next to snakes of different colors), and explained to participants why they could be misunderstood, unless they used complex NPs to give unambiguous instructions to their game partner, e.g., "The bird next to the brown snake is red."

Nozari and Omaki (2022) manipulated monitoring and control demands of sentence production using a finding from Gleitman et al. (2007), who showed that speakers tend to output a visually cued item first. Adapting this finding to the referential communication paradigm, Nozari and Omaki (2018) created two conditions: in the *Target-flash condition*, the target item (i.e., the animal(s) the color of which was to be described) flashed twice. This condition went along with the natural tendencies of the speakers to output the visually salient item first, and was thus low-demand. For example if the red bird was flashing in Figure 1, the target sentence started with the "*The bird [next to the brown snake is red]"*. In the high-demand *Cue-flash condition*, the cue item (i.e., the animal(s) next to the target animal) flashed twice. For example, the same sentence was elicited by flashing the brown snake next to the red bird in Figure 1. This condition was high-demand because speakers must overcome the tendency to use the visually salient noun as the subject and produce the sentence "The snake next to the red bird is brown." The task elicited the four types of sentences in each condition, shown in Table 1.

The results from 54 adult speakers showed that they rarely made agreement errors in the low-demand Target-flash condition when the head and local nouns had the same plurality. However, in the same condition, they reported (1) robust attraction errors (SP + PS > SS + PP) and the attraction asymmetry (SP – SS > PS – PP). Moreover, they reported two consequences for increased processing demands in the Cue-flash condition: (2a) an exaggerated attraction asymmetry (SP – SS >> PS – PP), and (2b) an increased rate of agreement errors on plural-head sentences (PS + PP). The absence of errors in congruent sentences under low-demand conditions, together with the findings described above points to online processing limitations as the source of agreement errors. Nozari and Omaki (2022) further confirmed this by showing a link between the two critical error types which increased under high cognitive load (SP and plural errors) and individual differences in inhibitory control.

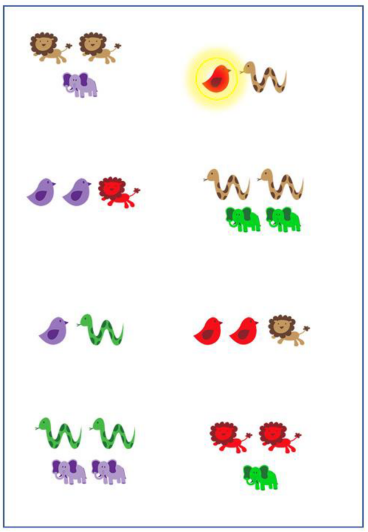

Figure 1: An example scene from the referential communication paradigm. In the Target-flash condition, the corresponding sentence would be "The bird next to the brown snake is red."

Table 1: Example target sentences for the SS, SP, PP, and PS types. Congruency refers to the number match/mismatch between the head and local nouns.

Sentence type		Example
SS	Singular Head, Congruent	The bird next to the brown snake is red.
SP	Singular Head, Incongruent	The bird next to the brown snakes is red.
PP	Plural Head, Congruent	The birds next to the brown snakes are red.
PS	Plural Head, Incongruent	The birds next to the brown snake are red.

Agreement production in children

Most experimental studies of agreement production in children are in French, using writing and/or preamble paradigms (where participants complete sentence fragments) which are particularly demanding on children's cognitive systems. The error patterns elicited from such studies suggest very different patterns of agreement errors in children and adults. The common finding is a default to singular, with no evidence of agreement attraction before the ages of 8-9 years. Even in the older age group which does show evidence of agreement attraction, the asymmetry of attraction typical of the adult data is missing (Fayol et al., 1999; Franck et al., 2004).

A recent study, however, investigated agreement production in 28 preschool English-speaking children using a memory paradigm (Lorimor et al., 2019). Children had to memorize the location of three pictured objects and repeat them back to the experimenter after the pictures had disappeared, using sentences like "The baby with the block(s) is on the bed." Although the task still had high demands on memory, it had the advantage of evoking conceptualization in children and having them produce sentences from meaning, rather than spelling-to-dictation or preamble tasks, in neither of which agreement production is rooted in children's conceptualization of events.

Interestingly, Lorimor et al. (2019) observed a qualitative pattern of agreement errors that showed both agreement attraction and the canonical attraction asymmetry. A quantitative comparison between the child and adult data, however, suggested differences. But it is important to note that the differences stemmed from an atypical pattern in adult speakers: surprisingly, their sample of adult speakers did not show the well-established attraction asymmetry. The study, unfortunately, did not analyze the child dataset separately to test whether the child data alone showed robust attraction and attraction asymmetry. Nevertheless, the findings suggest that the conclusion of different subject-verb agreement processes between adults and children may be premature.

Two possibilities are suggested by these contradicting findings: (1) The association between subject and its verb in children's language production system may be weak in the studied age groups (5–8-year-olds). Consequently, children's main strategy for verb production during this period may be defaulting to the more frequent singular form. This account is primarily an "*impoverished knowledge*" account, and would predict the pattern often reported in French: higher error rates in sentences with plural subjects and weak or non-existent evidence of attraction or attraction asymmetry even in older children ages 5-8 years. (2) Conversely, children's production systems may have formed strong and systematic associations between subject and verb plurality as early as 5 years of age, and deviations from these systematic associations may reveal limitations of online processing of a kind proposed by the models of agreement production in adults. This "*processing limitation*" account would predict the correct use of the plural verb in plural-subject sentences, along with evidence of agreement errors and agreement asymmetry, in children similar to adults.

Current study

The current study was designed to test the two possibilities discussed above. We tested children in the same referential communication paradigm as Nozari and Omaki (2018, 2022). Exp 1 included 5-7-year-old children. The minimum age of 5 years was selected because of the absence of attraction errors reported in 5-year-old French-speaking children. The maximum age was selected because although 7-8-year-old children did show evidence of attraction in the prior studies, they did not show the attraction asymmetry (Franck et al., 2004). Unlike Lorimor et al. (2019), we avoided a quantitative comparison with the adult sample, because children have both far less exposure to the statistics of language and less mature monitoring and control processes than adults, which is expected to create very different scales of errors. This can, in turn, create unstable interactions in statistical models (Rohrer & Arslan, 2021). What is of theoretical interest here is not a quantitative comparison of the effect sizes across populations, but rather the presence (or absence) of statistically robust attraction, attraction asymmetry, and sensitivity of agreement computations to processing demands in a way similar to the adult speakers.

To anticipate, the results of Exp 1 revealed the presence of attraction errors in children as young as 5 years of age, together with other similarities to the adult error pattern when processing demands were increased. One finding however, remained ambiguous: unlike adult speakers, children in this sample did not show a robust attraction asymmetry in the low-demand Target-flash condition. A closer examination of the data showed that this absence was due to the high rate of errors on SS sentences by the youngest group, a pattern that was not observed in older children. This left open the question: Do English-speaking children between 6-8 years of age show the attraction asymmetry? Exp 2 was designed to answer this question, as well as replicate the main finding of agreement attraction from Exp 1.

Experiment 1

Participants

Fifty-four neurotypical native English-speaking children between the ages of 5-7.5 years participated in the study. Three children were excluded because they were unable to follow the instructions. The remaining sample consisted of 18 5-year-olds, 15 6-year-olds, and 18 7-year-olds; 24 females, M_{age} = 6;5 years;months, SE = 0.12 years. Assignment of children to conditions was balanced, with the average age matched in Target-flash and Cue-flash conditions (6;5, SE = 0.18 vs. 6;5, SE = 0.18 years; $t(52) = 0.16$, $p = 0.88$).

Materials and Procedures

The same referential communication task used in Nozari and Omaki (2018; 2022) was presented in PowerPoint on a 15-

by-12 inch Dell monitor approximately 25 inches in front of the children. After a training phase with pen and paper, children were presented with scenes like Fig. 1 on the monitor. On each trial an animal (or a pair of animals) flashed, and children produced a sentence like "The bird next to the brown snake is red." to describe its color to the experimenter, who then colored the animal(s) the same way on her sheet. In the baseline Target-flash condition, the flashing animal was the target, i.e., the one whose color was to be described. In the Cue-flash condition, the flashing animal was the cue animal, i.e., the animal next to the target, who would appear in the prepositional phrase.

Each child within an age group was randomly assigned to one of the two conditions. Children completed 8 slides (+ 2 practice slides) each containing 4 trials, for a total of 32 sentences. The sentences were equally divided between SS, SP, PP, and PS types (see Table 1). Each animal appeared equally often in the target and cue positions across the two conditions. The experimenter pressed the space bar to start a trial. The trial began with a beep and two flashes of the target or the cue animal, depending on the condition, followed by a different beep 6.5 seconds later that marked the deadline of speaking (determined by pilot testing). To keep the child engaged, they checked the experimenter's work after each trial. Breaks were allowed whenever children needed them. Children finished the task within 30 minutes.

Results

All data were transcribed and coded by two native English speakers blind to the hypotheses of the study. Cohen's Kappa was 0.88, showing high inter-rater reliability. Cases of disagreement were reconciled by a third coder. Incomplete sentences (i.e., those without a verb) and sentences in which children produced the wrong plurality for either of the two nouns were excluded from the analysis. This led to the exclusion of about 10% of trials. Of the remaining 1472 trials, 336 contained a subject-verb agreement error. Only the child's first attempt on every trial was coded for errors. Subsequently, we coded whether the child spontaneously corrected their errors or not. The rate of agreement errors showed a slight and gradual decrease by age (24%, 23% and 21% in 5, 6, and 7 year-olds, respectively). But even in the eldest child group, the rate of agreement errors was still much higher than in adults in a similar task (~2%; Nozari & Omaki, 2018). Figure 2 shows the distribution of agreement errors across the four sentence types by condition. Error rates on SP sentences were particularly high (~50%), which brings up the possibility that children may simply be guessing what the right form is in these sentences. To address this possibility, we inspected monitoring performance on these trials. Out of 120 such errors, 56 (47%) were spontaneously corrected. This shows that the high error rate in this condition is not the result of children not possessing the knowledge of the correct verb form, but rather a failure in online computation of the correct agreement.

Analyses were done in R version 4.0.2., using a logistic variant of the generalized linear mixed model (GLMM) fit by maximum likelihood (Laplace Approximation) in the package lmerTest 3.1-3. The model contained Congruency (with two levels, congruent, i.e., SS + PP, vs. incongruent, i.e., SP + PS), Verb (with two levels, singular vs. plural), and Condition (with two levels, Target-flash vs. Cue-flash), and all the interactions between the three independent variables as its fixed effect. The maximum random effect structure tolerated by the model, i.e., the random intercept of subject and item was included, and binary variables were contrast coded (-0.5, 0.5). The results of any posthoc models reported below were corrected for multiple comparisons using the Bonferroni correction.

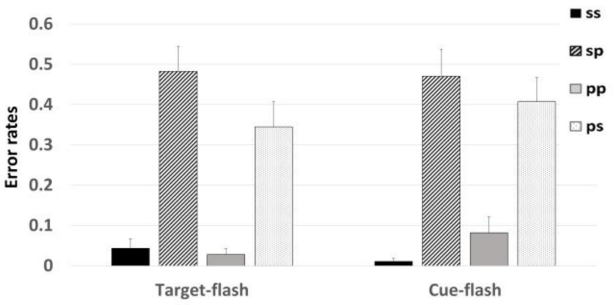

Figure 2: Average proportions of errors on verbs by condition and sentence type. Means of subject means are graphed, with error bars reflecting standard error. See Table 1 for examples of SS, SP, PP, and PS trials.

The results showed a main effect of Congruency, i.e., attraction, with SP and PS sentences eliciting more agreement errors than SS and PP sentences (43%, SE = 3% vs. 4%, SE = 1%, respectively; $\beta = 3.38$, $z = 12.49$, $p < .001$). A post-hoc model run on the youngest age group confirmed attraction even among 5-year-olds ($\beta = 4.44$, $z = 5.96$, $p < .001$). The main model also showed a significant Verb by Congruency interaction, i.e., the attraction asymmetry ($\beta = 1.43$, $z = 2.72$, $p = .006$). In addition, there was a significant Verb by Condition interaction ($\beta = 1.51$, $z = 2.99$, $p = .003$). This interaction marks the increase in the rate of plural errors in the Cue-flash compared to the Target-flash condition (mean of PP + PS: 25%, SE = 4% vs. 17%, SE = 4%, respectively), whereas the rate of singular errors showed no such increase (mean of SS and SP: 24%, SE = 4% vs. 26%, SE = 4%). Finally, there was a significant three-way interaction between Verb, Congruency, and Condition ($\beta = -2.43$, $z = -2.41$, $p = .016$). This interaction implies that the Verb by Congruency (i.e., the asymmetry of attraction) differs between the two conditions. To unpack this, we ran post-hoc analyses on subsets of the data containing Target-flash and Cue-flash conditions, separately. After correcting for two comparisons, there was a robust Verb by Congruency interaction in the Cue-flash ($\beta = 2.64$, $z = 3.24$, $p = .001$), but not in the Target-flash condition ($\beta = 0.21$, $z = 0.35$, $p = .728$). The absence of the attraction asymmetry in the low-demand Target-flash condition was due to the relatively high rate of errors in the

SS sentences (4%, SE = 2%), the majority of which was committed by the 5-year-old children.

Discussion

Experiment 1 yielded three results: 1) English-speaking children, even the youngest group, showed a clear attraction effect in agreement production. 2) Increasing demands on sentence planning increased the rate of plural errors. 3) Attraction asymmetry was apparent under the high-demand Cue-flash, but not the low-demand Target-flash, condition.

The first two findings were similar to the results obtained from the adults from the same paradigm (Nozari & Omaki, 2022), providing support for the processing limitation hypothesis in children. The third finding, however, requires more deliberation. Although attraction asymmetry was exaggerated in the high-demand condition, adults showed the asymmetry robustly in the low-demand condition as well, whereas children did not. A closer inspection of the data revealed that a possible cause for the absence of attraction asymmetry in the low-demand condition may be the relatively high rate of errors in the SS condition, committed almost exclusively by the 5-year-old children. This finding provides some support for the impoverished knowledge hypothesis of subject-verb agreement in children before the age of 6. Interestingly, the current data suggest that this impoverishment is not always in the form of defaulting to the singular form, but rather the loose association between subject and verb may manifest as the production of the plural verb in singular-subject sentences without attractors.

To summarize, the findings of Exp 1 suggested a mixture of impoverished subject-verb agreement knowledge and processing limitations in 5-year-old English-speaking children, whereas the pattern of results in children 6 years of age and older was compatible with a pure processing limitation account, similar to the adult speakers. Exp 2 aimed to replicate the main finding of Exp 1, i.e., agreement attraction, and to specifically test for the presence of the attraction asymmetry under low-demand conditions in children 6-8 years of age.

Experiment 2

Participants

The effect size from Nozari & Omaki (2018) for the attraction asymmetry in the Target-flash condition in the adult data (0.86) was used to estimate the required sample size for a two-tailed within-subject test with $\alpha = 0.05$ and power of 0.95, which was determined to be 20 participants (G* 3.1.9.7). We ran 21 children with the age range of 6-8.5 years (13 6-year olds, 23 7-year olds, and 11 eight-year olds; 12 females, average age was 7;4, SE = 0.17 months).

Materials and Procedures

Materials and procedures were identical to Exp 1. Only the Target-flash condition was used.

Results and Discussion

Transcription, coding, and analysis followed the same procedures as Exp 1. Similar to Exp 1, plurality errors on nouns and incomplete sentences were excluded from analyses (5% of the total data). Of the remaining 637 sentences, 179 contained a subject-verb agreement error. Figure 3 shows the pattern of agreement errors in Exp 2. The rate of SP errors was even higher in Exp 2 than in Exp 1 (60%), but the rate of spontaneous corrections on these errors was also higher (67%, with all age groups correcting at least 1/3 of their SP errors), again suggesting that these are not knowledge, but processing, errors.

A model with Verb and Congruency and the interaction between the two as fixed effects, as well as random effects of subjects and items showed a significant effect of congruency, i.e., agreement attraction, ($\beta = 3.85$, $z = 9.24$, $p = < .001$), and a significant interaction between verb and congruency, i.e., the asymmetry of agreement attraction, ($\beta = 2.02$, $z = 2.51$, $p = .012$). In short, Exp 2 replicated the agreement attraction effect reported in Exp 1, and also confirmed the presence of the asymmetry of attraction in children older than 5, under normal processing loads.

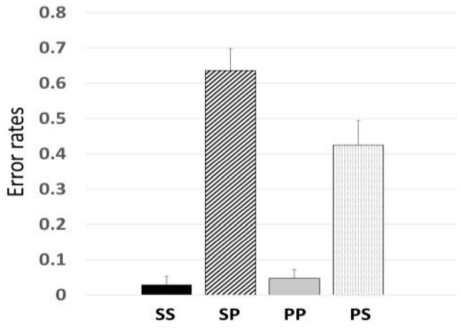

Figure 3: Average proportions of errors on verbs by sentence type. Means of subject means are graphed, with error bars reflecting standard error.

General Discussion

The purpose of this study was to revisit the notion that syntactic processes that rely on long-distance dependencies, such as subject-verb agreement in sentences with complex NPs, are different in children and adults. The evidence for such a view came primarily from studies in French, which has a different morphonolgical system than English, and through paradigms that require orthographic knowledge, and/or had other demands such as high working memory load, which may conceal children's true processing abilities. Those studies generally supported weak subject-verb associations in children, with defaulting to singular forms and weak or absent attraction and attraction asymmetry.

Using a referential communication game suitable for children as young as 5 years of age, we demonstrated that the pattern of agreement errors in children is, in fact, quite similar

to adult speakers. Exp 1 found robust evidence of agreement attraction, even in the youngest child group. Moreover, an increase in processing demands increased the rate of errors on plural-subject sentences, just like in adults, providing some support for the default status of the more frequent singular form (e.g., Eberhard et al., 2005). Importantly though, this effect is neither exclusive to children, nor the most prominent piece of evidence for weak subject-verb associations. Some of the 5-year-old children in the current study mistakenly used plural verbs in SS sentences, showing that in this age group, the knowledge of subject-verb agreement in production may not yet be solid. Older children did not make this mistake, and their error patterns were generally similar to adults. Exp 2 replicated the findings of Exp 1 in 6-8 year-old children, and also demonstrated a robust attraction asymmetry in this group under normal sentence processing demands. Together these findings suggest a mixture of impoverished knowledge and processing limitation as the source of agreement errors in 5-year-old children, with older children's agreement errors driven mostly by processing limitations that are qualitatively very similar to the adult speakers.

Why are our results —and conclusions— different from prior studies on the subject? There are several valid reasons for these discrepancies: first, as mentioned earlier, plural cues are often silent in spoken French. Thus, French-speaking children have fewer prominent and unambiguous cues to rely on in their auditory input. They learn the distinction between singular and plural forms more reliably once they begin to learn French orthography, but the degree of exposure to text and the variability in children's rate of orthographic learning make agreement production in French-speaking children less systematic and stable than their English-speaking peers. Second, when the task requires orthographic knowledge, or the child completes a sentence fragment that they have not originally planned, the demands are not comparable to sentence production in conversational settings. It is thus reasonable to expect different patterns of performance in those studies and ours, in which no memorization was required, and children planned their sentences with a communicative goal.

Most comparable to the current study, in terms of paradigm and language, was Lorimor et al.'s (2019) study in preschool children. Although the authors' comparison to an atypical pattern of adult data led to the conclusion that children and adults have different agreement production mechanisms, the error pattern produced by children was strikingly similar to that reported in the current study. Also similar to the current study, younger children sometimes defaulted to one form of the verb or another in all their responses, which led to unusually high error rates. That study, however, did not include children 6 years and older, who have been the target of the French studies and the current study. In short, the current results from the younger children are largely similar to those reported by Lorimor and colleagues but add to them by showing that around the age of 6, children as a group begin to show all the properties of adult-like agreement production, albeit with much lower proficiency.

To summarize, these results provide the first evidence that the computations underlying subject-verb agreement production, and more generally syntactic operations relying on long-distance dependencies, are similar in children and adults. This is despite the fact that the error rates on similar tasks differ by an order of magnitude between the two age groups, which points not just to less exposure to structures with complex NPs (see Lorimor et al., 2019 for a corpus analysis), but also to the less mature cognitive processes that have been shown to play a role in agreement computations, such as working memory, monitoring and inhibitory control (Hartsuiker et al., 2003; Nozari & Omaki, 2022).

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