The Role of Executive Control in Agreement Attraction in Monolingual and Bilingual Children

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1. Introduction

1.1. Attraction errors

In 2015, Facebook followers of the British-American rock band Fleetwood Mac may have seen the message "Tickets for night #2 of Fleetwood Mac in Amsterdam is now on sale!" on their timelines. Although it was very nice of the band to schedule an additional concert after the first night was sold out within an hour, something about this message was off. The writer had committed an attraction error. The subject of the sentence, *tickets*, does not agree in number with the verb, *is*. In their seminal study, Bock and Miller (1991) found that these errors typically occur in sentences where the head and local noun mismatch in number (e.g., *the key to the cabinets **are** missing*). The verb is 'attracted' to agree with a local noun (a noun that occurs between the head noun and the verb, here *cabinets*), rather than with the subject's head noun, *key*. Seeing how (some form of) agreement has to be computed in almost every sentence we produce, it is important to understand the processes that underlie our computation of number from mental message to sound wave. Attraction errors can help us gain traction on these processes and where they can go wrong.

Bock and Miller (1991) used a preamble completion task to elicit attraction errors. The participants were presented with a subject phrase, which they had to repeat and complete by adding an inflected verb phrase. This paradigm has been used in the majority of agreement production studies and lends itself to meticulous manipulation of the grammatical and conceptual characteristics of the subject phrase and their influence on the agreement process. These studies have shown, for example, that plural local nouns yield more attraction errors than singular local nouns (Bock & Miller, 1991; Eberhard, 1997; Haskell & MacDonald, 2005). If the head noun has a number-ambiguous determiner, it is more vulnerable to attraction than when it has an unambiguous singular

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Proceedings of the 41st annual Boston University Conference on Language Development, ed. Maria LaMendola and Jennifer Scott, 706-717. Somerville, MA: Cascadilla Press.

determiner (Antón-Méndez & Hartsuiker, 2010; Hartsuiker, Schriefers, Bock & Kikstra, 2003). Local nouns more frequent in their plural form exert stronger attraction than local nouns more frequent in their singular form (Barker & Nicol, 2000). The linear distance between the head noun and the verb influences agreement (Bock & Cutting, 1992; Gillespie & Pearlmutter, 2013) as well as the syntactic distance between the head and local nouns (Franck, Vigliocco, & Nicol, 2002).

Although subject-verb agreement is syntactic operation, the process is sensitive to conceptual influences as well. Local nouns that are semantically related to the head noun, exert stronger attraction than those that are not related (Barker, Nicol, & Garrett, 2001). If the local noun would be a plausible subject for the verb, it exerts stronger attraction than when it would not be a plausible subject (Thornton & MacDonald, 2003). When the head noun is a collective (grammatically singular, but with a plural notion, e.g., *team*), it is more vulnerable to plural attraction than when it is notionally singular (Haskell & MacDonald, 2003). Distributed phrases (grammatically singular, but notionally plural, e.g., *the label on the bottles*) are more vulnerable to plural attraction than notionally singular phrases (Bock, Carreiras, & Meseguer, 2012; Vigliocco, Butterworth, & Garrett, 1996). Subject phrases where the head and local noun are semantically strongly integrated (thus, notionally singular, e.g., *the bowl with the stripes*) are less vulnerable to plural attraction than weakly integrated subject phrases (e.g., *the bowl with the spoons*; Brehm & Bock, 2013; Veenstra, Acheson, Bock, & Meyer, 2014).

1.2. Executive control and attraction

Whereas a lot is known about the linguistic context in which attraction errors occur, less is known about the cognitive context in which they are produced. Why do healthy native speakers make these errors and why are some speakers more susceptible to attraction than others? Some studies have argued for the involvement of executive control. Executive control refers to a domain-general cognitive system in the prefrontal cortex that is critical for the flexibility and regulation of cognition and goal-directed behavior (Best, Miller, & Jones, 2009). So far, only a small number of studies have implicated working memory (WM) as the part of executive control that modulates attraction.

Bock and Cutting (1992) found a very weak WM effect: They conducted three preamble completion experiments and had the participants perform a speaking span task (Daneman & Green, 1986). The authors found in one of the three experiments that a higher speaking span led to fewer agreement errors. The evidence from Hartsuiker and Barkhuysen (2006) is more compelling: They used a preamble completion task in which half of the participants received a concurrent WM load, whereas the other half did not. More agreement errors were made in the load condition compared to the no-load condition. In addition, participants performed a speaking span task. Poor performance on the WM task was related to high agreement error rates. Finally, Slevc and Martin (2016) had

patients with grammatical and WM deficits produce agreement. Independent of the grammatical deficit, the degree of WM impairment affected agreement error rates: Poor WM increased the vulnerability to attraction.

1.3. Executive control and bilingualism

A popular line of research into bilingualism is the effect that speaking more than one language has on non-linguistic cognitive development. Some studies have reported a bilingual advantage where bilingual children outperform monolingual children on several executive control tasks. This cognitive advantage seems to stem from the challenges that bilinguals face when using two language systems. Both language systems are active in the mind, and as only one can be used at the same time, distraction from the other language needs to be prevented. This control over conflicting and distracting information may generalize to other domains. Also the fact that bilinguals have to switch fast and regularly between their language systems seems to increases their general cognitive control. Advantages have been found in WM (Blom, Küntay, Messer, Verhagen, & Leseman, 2014; Morales, Calvo, & Bialystok, 2013), inhibitory control tasks and switching tasks (Bialystok, 1999; Bialystok & Martin, 2004; Prior & MacWhinney, 2010). Adesope and colleagues wrote an extended review and report also advantages in metalinguistic awareness, metacognitive awareness, abstract reasoning, and problem solving (Adesope, Lavin, Thompson, & Ungerleider, 2010).

1.4. Hypotheses

Although the exact role of WM in agreement production is debated, some studies have argued in favor of memory based models. More specifically, cue-based memory retrieval models can account for linguistic factors affecting agreement as well as individual differences in susceptibility to attraction (e.g., Badecker & Kuminiak, 2007; Slevc & Martin, 2016; Thornton & MacDonald, 2003). On this account, agreement is computed just before the production of an inflected verb. At this point, the agreement controller has to be selected from elements active in memory. Normally, the head noun of the subject phrase is selected as agreement controller based on retrieval cues (most importantly, grammatical subject-hood, but also other cues such as semantic compatibility with the verb). However, other elements—such as a recently produced local noun—can be mistakenly selected as well, especially when they share some of the cues with the head noun. We assume that these cues determine the relative activation of the elements, facilitating selection of the correct agreement controller.

We hypothesize that WM is needed to keep the number of the head noun activated in memory until it has to be retrieved as an agreement controller for the verb. Speakers who have a poor WM may not be able to maintain sufficient activation of the head noun number, thus increasing the relative activation of the

local noun, and thereby the chance of producing an attraction error. In addition, we hypothesize that inhibitory control is needed to prevent the local noun from being selected as an agreement controller. Speakers with a poor inhibitory control might be more likely to produce attraction errors.

In this study, we investigated how WM skills and inhibitory control are related to the production of attraction errors. To increase the variability in executive control, we included a group of bilingual speakers, in addition to a group of monolingual speakers. These bilingual speakers may arguably have better executive control, which might make them less vulnerable to attraction compared to monolingual speakers. In contrast to previous studies employing the preamble completion paradigm (including the studies implicating WM), we used a picture description task. Whereas the repetition of the subject phrase (as is part of the preamble completion paradigm) might depend heavily on available WM, describing a picture may rely less on WM. Therefore, any effects of WM in the current experiment may be more directly related to the agreement process compared to the preamble completion paradigm.

2. Method

2.1. Participants

Forty-four children were monolingual speakers of Dutch, recruited in Eindhoven, the Netherlands (mean age = 11;1, *SD* = 7 months, 25 girls). Forty-eight children were early sequential bilingual speakers who spoke exclusively French at home and Dutch in school, recruited in Brussels, Belgium (mean age = 11;1, SD = 7 months, 28 girls). The bilingual speakers started learning Dutch upon entering the educational system at age 2;6.

Ethical approval for the study was provided by the ethical board of the Université Libre de Bruxelles. Informed consent was obtained from the children's parents before the study. None of the children included had language- or developmental problems. The parents filled out a language background questionnaire (adapted from *ALEQ*, Paradis, 2011), to ensure that all children had parents who both exclusively spoke the home language at home.

2.2. Executive Control measures

We used the digit span task from the CELF 4-NL to measure verbal WM (Kort, Schittekatte & Compaan, 2008). This paper-and-pencil task consisted of a forward and a backward part. In the first part, the experimenter read out a series of digits, one per second, which the participant had to repeat verbatim. In the second part, the series of digits had to be repeated in the reversed order. After two correct series, the next series increased with one digit, until the participant made two consecutive errors which then ended the task. The score consisted of the number of correct trials.

We used the Corsi Blocks task from the PEBL Psychological Test Battery to measure non-verbal WM (Mueller & Piper, 2014). The task was presented on

a laptop and showed 9 blue squares. The squares lighted up in a certain pattern, which the participant had to reproduce by clicking on the squares in the same (in the first part), or reversed order (in the second part). Similar to the digit span task, a series was increased with one square after two correct answers, and terminated after two incorrect answers. The score consisted of the number of correct trials.

We used the Attentional Networks Task (Rueda, et al, 2004), to measure inhibitory control. The task measures three kinds of attention: alerting, orienting, and interference skills, but we focus on the interference measure. In a flanker-like setting, five fish appear on a computer screen. Participants have to press the left or right button to indicate the direction in which the middle fish is swimming. Sometimes the flanker fish swim in the same direction, sometimes in the opposite direction. The interference score consist of the difference in response time between the two conditions, with a higher score indicating stronger interference, thus weaker inhibitory control.

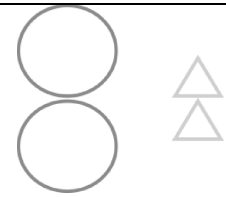
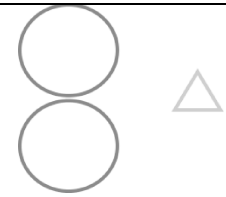
In addition, we used a switching task. Switching between task settings involves an inhibition component which prevents the participant from continuing with the previous task when a new task has started. We used the color-shape task (digitalized by Ellefson, Shapiro, & Chater, 2006). Here, participants saw a display with a large object (a circle or triangle that was either red or blue) in the middle. In the bottom left and right corners there were two smaller objects, one of which matched the large object in color, while the other one matched it in shape. Depending on the cue at the top of the screen, participants had to select the small object that matched in color or shape with the large object by pressing the left or right button. In half of the experiment, the shape and color criteria were mixed across trials. The difference in response times between the switching and non-switching trials in these mixed blocks represents the participants' switch cost. Higher values represent higher switch cost, thus weaker inhibition.

2.3. Agreement

We adapted the picture description task from Veenstra, Acheson, & Meyer (2014), which is very suitable to use with children because of the simple objects and words (circles, triangles, and stars). The agreement task had a 2 (head noun number: singular/plural) by 2 (number match: match/mismatch) within-subjects design. This yielded sentences with singular head nouns combined with matching singular local nouns, or mismatching plural local nouns. It also included sentences with plural head nouns combined with matching plural local nouns, or mismatching singular local nouns. Early studies on agreement production using the preamble completion paradigm found negligible attraction from singular local nouns when the head noun was plural (Bock & Miller, 1991; Eberhard, 1997). Recently, however, studies using different methodologies have found that singular local nouns can also exert attraction (Franck et al., 2002; Veenstra, et al., 2014; Veenstra, et al., 2015).

Pictures of simple arrays of objects were presented on a laptop. The pictures always consisted of one or two brightly colored shapes on the left hand side, and one or two smaller grey colored shapes on the right hand side, see Table 1.

Table 1.
Example item from the picture description task in four conditions

	Singular head	**Plural head**
Number match		
	De cirkel naast de driehoek 'The circle next-to the triangle'	*De cirkels naast de driehoeken* 'The circles next-to the triangles'
Number mismatch		
	De cirkel naast de driehoeken 'The circle next-to the triangles'	*De cirkels naast de driehoek* 'The circles next-to the triangle'

The participants were instructed to produce a sentence starting with the left object(s), the head noun, followed by the right object(s), the local noun, always using *next to* (*naast*, in Dutch) to connect them and end with an inflected verb phrase that included the color of the head noun (e.g., *de cirkel naast de driehoek is blauw*, 'the circle next-to the triangle is blue'). See the Appendix for the full list of items. The participants were encouraged to have finished their sentence by the time the picture disappeared from the screen (after 3000 ms). The audio recording of the responses continued into the next trial, until the next picture appeared on the screen.

The participants were given 6 examples of pictures and their descriptions, followed by three practice blocks consisting of 10 trials each. Extra instruction was given when needed during the practice phase. The actual experiment consisted of three blocks of 24 trials each. Each block had 6 trials in which the head and local noun were both single, 6 trials in which the head and local noun were both plural, 6 trials in which the head noun was single and the local noun plural, and 6 trials in which the head noun was plural and the local noun singular, in a fixed random order. All participants saw all items in all conditions, 72 in total. Answers were both recorded and noted by the experimenter. This task took around 20 minutes.

3. Results

First, we compared the scores on the executive control measures for bilingual children with those of the monolingual children. Using ANOVAs, we found that there was only one measure on which the two groups differed significantly: the monolingual children performed better on the forward version of the Corsi Blocks compared to the bilingual children: F (90) = 4.96; p <.05. None of the other measures were significantly different. We also compared the attraction error rates (the percentage of errors on all mismatching conditions combined for each participant) between the two groups, and only found a marginal difference, with bilingual children making fewer attraction errors than monolingual children: F (90) = 3.325; p = .072. This numerical difference can be seen in Figure 1 which shows the agreement error rates in all four conditions:

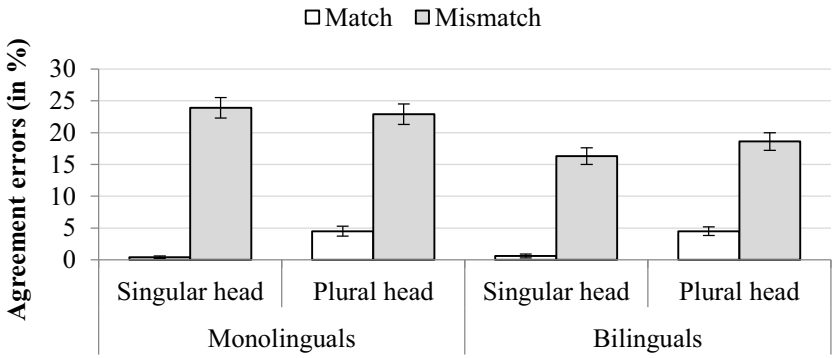


Figure 1. Agreement errors across the language groups. Error bars represent the standard error (*SE*) across participants.

Second, we used a linear mixed effects regression model (LMER) to analyze the agreement error rates using a logistic linking function (Bates, 2005; Jaeger, 2008). Random intercepts were included for subjects and items, as well as random slopes to subjects and items for Head Noun Number, Number Match and their interaction, see Table 2:

Table 2.
LMER model predicting agreement errors.

Variable	Estimate	*SE*	*z*-value	*p*-value
(Intercept)	-3.55	0.74	-4.80	0.000
Head Noun Number	1.32	0.34	3.84	0.000
Number Match	2.84	0.60	4.73	0.000
Language Group	-0.22	0.26	-0.83	0.405
Match x Head Noun Number	-1.29	0.34	-3.85	0.000
Match x Language Group	-0.14	0.20	-0.70	0.487

The results showed a main effect of Head Noun Number, with more errors for plural head sentences than for singular head sentences. There was also a main effect of Number Match, with more errors for sentences where the head noun mismatched in number with the local noun than for sentences with matching nouns. This effect was stronger for the singular head sentences (β = 3.94; *SE* = 0.78; z = 5.03; p <.001) compared to the plural head sentences (β = 1.20; *SE* = 0.14; z = 8.48; p <.001). Finally, there was no effect of Language Group.

The final analysis looked at the mismatching conditions only. An LMER was used to predict attraction errors by the executive control measures. Again, random intercepts were included for subjects and items, as well as random slopes to subjects and items for Head Noun Number, see Table 3:

Table 3.
LMER model predicting agreement errors by executive control measures.

Variable	Estimate	*SE*	*z*-value	*p*-value
(Intercept)	0.50	0.87	0.58	0.565
Head Noun Number	0.04	0.07	0.55	0.582
Digit span forward	-0.09	0.07	-0.40	0.162
Digit span backward	-0.20	0.06	-3.06	0.002
Corsi blocks forward	0.25	0.15	1.70	0.088
Corsi blocks backward	-0.32	0.12	-2.73	0.006
ANT interference	0.00	0.00	1.36	0.174
Switch cost	0.00	0.00	0.84	0.400

There was a main effect of backward digit span task scores, indicating that children with a higher score made fewer attraction errors. There was also a main effect of backward Corsi Blocks task scores, indicating that children with a higher score made fewer attraction errors. *P*-values for the effects of the forward versions of the digit span, Corsi Blocks, and ANT tasks were low, but not significant.

4. Discussion

In this paper, we investigated the influence of executive control on the susceptibility of young speakers to number attraction. We elicited agreement errors in monolingual and bilingual children and studied the effect of their individual differences in working memory and inhibitory control on the error rates.

First of all, unlike some studies who found a bilingual advantage in executive control, our bilingual children did not differ much from our monolingual children in verbal WM, non-verbal WM, or inhibitory control. The only significant difference was on the forward version of the Corsi Blocks task, and was in favor of the monolingual group, rather than the bilingual group.

There are several possible explanations for this lack of an effect of bilingualism. Some studies argue that the bilingual advantage is dependent on the degree of bilingualism. For example, more daily switching between languages and good proficiency in both languages lead to stronger advantages, compared to less switching and unbalanced proficiency (Bosma, Blom, & Versloot, 2017; Prior & Gollan, 2011, see also Crivello et al., 2016). The bilingual children in our study were sequential bilinguals, who grew up in French and learned Dutch in school later on. The vast majority of pupils had an exclusively Francophone background and used Dutch only during school hours. This suggests not only that their French might be dominant over their Dutch, but also that this strict division between the French and Dutch language situations did not provide much opportunity for language switching, and, thus, no bilingual advantage.

On the other hand, a growing number of studies have not found any differences between monolingual and bilingual speakers in executive control at all (e.g., Antón, et al., 2014; Engel de Abreu, 2011; Paap & Greenberg, 2013). Null results may be due to certain intricate factors (in the task or participants) that were not ideal for finding differences (Costa, Hernández, Costa-Faidella, & Sebastián-Gallés, 2009). However, Paap and Greenberg argue that bilingual advantages are caused by Type 1 errors, inadequately matched groups, cultural differences and the poor connection between tasks and the construct that they are supposed to measure (Paap & Greenberg, 2013: 255; for a similar account, see Hilchey & Klein, 2011).

In the absence of a bilingual advantage, we were still able to study the effect of executive control on agreement attraction. Even though the two language groups did not differ from each other, within each of the groups there was a variation in the executive control measures that we used to predict attraction error rates. We found that scores on the backward versions of both the verbal and the non-verbal WM tasks affected error rates. Children with higher WM scores made fewer agreement errors. The backward versions of the memory tasks require information to be held in memory, manipulated, and reproduced. We argue that this is similar to the way the subject head noun has to be held in memory, retrieved, and used as an agreement controller.

While cue-based memory retrieval accounts would predict this effect of WM on agreement attraction (e.g., Badecker & Kuminiak, 2007), in this paper, we also predicted that inhibitory control would play a role. We measured inhibitory control with the interference score from the ANT task, and the switch cost from the Color-Shape task. Although both *p*-values were low and in the predicted direction (children experiencing more interference from incongruent flanker trials and children experiencing stronger delays after a task has switched made more attraction errors than children who experienced less difficulties), we cannot make any claims based on these results. Whether the null-effect is a power issue, or a matter of having used the wrong tasks, or whether inhibitory control is even necessary during agreement production, is an issue for further research.

Appendix

Table A.

List of items from the picture description agreement task (in Dutch)

Head noun		Local noun	Verb	
De cirkel(s)	naast	de driehoek(en)	is/zijn	rood/blauw/geel
De cirkel(s)	naast	de ster(ren)	is/zijn	rood/blauw/geel
De driehoek(en)	naast	de cirkel(s)	is/zijn	rood/blauw/geel
De driehoek(en)	naast	de ster(ren)	is/zijn	rood/blauw/geel
De ster(ren)	naast	de cirkel(s)	is/zijn	rood/blauw/geel
De ster(ren)	naast	de driehoek(en)	is/zijn	rood/blauw/geel

Note. Plural markings are presented in brackets.

Table B

List of items from the picture description agreement task (English translations)

Head noun		Local noun	Verb	
The circle(s)	next-to	the triangle(s)	is/are	red/blue/yellow
The circle(s)	next-to	the star(s)	is/are	red/blue/yellow
The triangle(s)	next-to	the circle(s)	is/are	red/blue/yellow
The triangle(s)	next-to	the star(s)	is/are	red/blue/yellow
The star(s)	next-to	the circle(s)	is/are	red/blue/yellow
The star(s)	next-to	the triangle(s)	is/are	red/blue/yellow

Note. Plural markings are presented in brackets.

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Proceedings of the 41st annual Boston University Conference on Language Development

edited by Maria LaMendola
and Jennifer Scott

Cascadilla Press Somerville, MA 2017

ISSN 1080-692X
ISBN 978-1-57473-076-0 (2 volume set, paperback)
ISBN 978-1-57473-176-7 (2 volume set, library binding)

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