Resisting Attraction: Individual Differences in Executive Control Are Associated With Subject–Verb Agreement Errors in Production

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We propose that attraction errors in agreement production (e.g., the key to the cabinets *are* missing) are related to two components of executive control: working memory and inhibitory control. We tested 138 children aged 10 to 12, an age when children are expected to produce high rates of errors. To increase the potential of individual variation in executive control skills, participants came from monolingual, bilingual, and bidialectal language backgrounds. Attraction errors were elicited with a picture description task in Dutch and executive control was measured with a digit span task, Corsi blocks task, switching task, and attentional networks task. Overall, higher rates of attraction errors were negatively associated with higher verbal working memory and, independently, with higher inhibitory control. To our knowledge, this is the first demonstration of the role of both working memory and inhibitory control in attraction errors in production. Implications for memory- and grammar-based models are discussed.

Keywords: agreement production, number attraction, executive control, memory retrieval

In many languages, including Dutch and English, verbs agree in number with the head of their subject phrase (e.g., *the key* to the cabinets *is* missing). Speakers are known to sporadically produce *attraction errors*, where the verb agrees with a noun that is not the head of the subject phrase (e.g., the key to *the cabinets are* missing; Bock & Miller, 1991). Although *key* is the (singular) head noun, the verb is attracted to the (plural) local noun *cabinets* instead, leading to an (incorrectly plural) attraction error.[1] Many studies have varied the characteristics of the subject phrase to investigate the influence of its grammatical and conceptual features on the agreement process (see Häussler, 2012, for an overview). These studies taken together provide valuable insights into how concepts are turned into language, and what factors play a role when this process goes wrong. To date, the reported patterns are general, they apply to the whole population at large, and not many studies have investigated individual differences in susceptibility to attraction.

A number of accounts of attraction have been proposed to explain elicited production data (see Bock & Middleton, 2011).[2] Some of them are grammatical in nature, such as the hierarchical feature passing account (Franck, Vigliocco, & Nicol, 2002). On this account, the number feature of the subject head noun 'travels up' the syntactic tree to the sentence node, from where it is copied onto the verb (Vigliocco, Butterworth, & Semenza, 1995). However, sometimes the number features of other nouns (e.g., a mismatching local noun) reach the top node first and manage to copy their specifications to the verb, leading to attraction errors. Another grammatical attraction account is the marking and morphing model (Eberhard, Cutting, & Bock, 2005). This model predicts the proportion of plural verbs with a formula that takes into account the number properties (both grammatical and conceptual number) of the constituents of the subject phrase. For example, a singular head noun that is conceptually plural (such as *team*) leads to more

[1] Attraction errors are a certain type of agreement error, in which the verb is 'attracted to' a wrong noun. This type of error is the focus of the current article; therefore, we will refer to them as *attraction errors*, even though the term *agreement error* would also be correct, but not as informative.

[2] We do not intend to give a full overview of all accounts in the literature and limit our review to three key accounts.

incorrect plural verbs when combined with a plural local noun than a head noun that is both grammatically and conceptually singular. Both accounts in their current implementation do not incorporate a role for working memory (WM), although the idea that it might cannot inherently be ruled out. The final model we mention here, the scope of planning account, is memory-based, rather than grammar-based. Pearlmutter and colleagues (Gillespie & Pearlmutter, 2011a, 2011b, 2013; Solomon & Pearlmutter, 2004) have argued that attraction occurs if two mismatching nouns are planned simultaneously before speech onset. When the nouns are planned in parallel, the interfering number features are active at the same time and lead to more attraction errors, compared with when the nouns are planned incrementally (but see Brehm & Bock, 2013; Veenstra, Acheson, Bock, & Meyer, 2014, and Veenstra, Meyer, & Acheson, 2015 for an alternative explanation). This account could in theory predict individual differences by way of a variable scope of planning: speakers with larger scopes would be more likely to make attraction errors. However, this hypothesis has not been directly tested to date.

Whereas the accounts described in the preceding text are successful in explaining grammatical (and conceptual) influences on agreement, they do not readily explain variation in attraction error rates across participants: some speakers seem to be more prone to produce attraction errors than others. A recent patient study suggested that it is not grammatical skills (alone) that affect agreement production, but that cognitive skills play a role as well. Slevc and Martin (2016) tested the production of subject–verb agreement in brain-injured patients with grammatical deficits and WM deficits, and found that the degree of the WM deficit influences agreement production, more so than the degree of the grammatical deficit. On the basis of this finding, they argued in favor of memory-based accounts of attraction.

A few studies have suggested that WM plays a role in agreement production in neuro-typical adult speakers as well. Bock and Cutting (1992) conducted three experiments in which they correlated the performance of participants on a speaking span task (Daneman & Green, 1986) with attraction errors and general subject phrase repetition errors. On all experiments, a lower speaking span increased repetition errors, whereas in one experiment (Experiment 2), the speaking span affected the attraction errors as well: participants with a higher speaking span made fewer attraction errors. Hartsuiker and Barkhuysen (2006) conducted a study in which they gave half of the participants a WM load during an agreement production task. These participants had to remember a list of three words before each agreement trial, and reproduce them after the trial. The other half of the participants only completed the agreement trials. All participants performed a speaking span task. Overall, more attraction errors were made for the WM load condition compared with the no-load condition and a lower speaking span was related to a higher attraction error rate. More specifically, low-span speakers showed a load-effect, whereas high-span speakers did not.

Although the exact role of WM in agreement production is debated, memory-based accounts (which may not be specific to agreement attraction) seem promising in explaining individual differences in agreement production. Badecker and Kuminiak (2007) studied gender attraction in subject–verb agreement in Slovak. They conducted three experiments in which they manipulated the gender and case of head and local nouns of the subject phrase. They found that the gender of a local noun can attract agreement, an effect that was modulated by the grammatical case of the attractor. The authors argued for a cue-based retrieval model: prior to the production of the verb, the production process looks back and needs to find an agreement controller in a collection of active and recently produced elements. It uses cues to find the right controller, and if a local noun shares a number of these cues with the head noun, it can get incorrectly retrieved and used as agreement controller (see also Thornton & Macdonald, 2003). The success of the retrieval is dependent on WM resources keeping the different elements activated. This backward-looking retrieval account contrasts with the forward-looking scope of planning account, which posits the number conflict during the advance planning stage, rather than the moment just prior to the production of the verb. In any case, both memory-based models predict individual differences based on WM.

Previous work on agreement comprehension shows patterns comparable to production: Pearlmutter, Garnsey, and Bock (1999) found that readers slowed down when head and local nouns mismatched in number, compared with when they matched. This slowdown was more pronounced for singular head nouns combined with a plural local noun than vice versa, an asymmetry often found in production (Bock & Eberhard, 1993). Sensitivity of readers to conceptual number mismatches has also been reported (Nicol, Forster, & Veres, 1997). It has been debated whether the same mechanisms are at play during production and comprehension, with some arguing for memory retrieval accounts for comprehension, but head noun number representation accounts (such as the marking and morphing account in the preceding text) for production (Tanner, Nicol, & Brehm, 2014). As in production, memory-based models in agreement comprehension can account for individual differences based on working memory. Reifegerste, Hauer, and Felser (2016) found an effect of WM in older adults in a grammaticality judgment task and a reading task: low memory span participants were slower to judge and read sentences with mismatching head and local nouns. Other studies suggest that these retrieval processes are at work even when there is no mismatch (Martin, Nieuwland, & Carreiras, 2012, 2014).

In summary, two memory-based production models are compatible with an association between individual differences in WM and rates of agreement attraction errors in production, the Scope of Planning account (Gillespie & Pearlmutter, 2011b) and the cue-based memory retrieval account (Badecker & Kuminiak, 2007). The empirical basis to date consists of three studies (Bock & Cutting, 1992: Experiment 2; Hartsuiker & Barkhuysen, 2006; Slevc & Martin, 2016), two with neuro-typical adults and one with patients. In all cases, individuals with lower WM skills produced more agreement attraction errors.

In addition to WM influencing agreement attraction in production, we also propose that inhibitory control ought to play a role in the process. Take, for example, the sentences with a complex subject phrase that we are using in the experiment reported in the following text, where the head noun is modified with a prepositional phrase containing a local noun (e.g., "the circle next to the triangles is blue"). If we were to explore the predictions of the cue-based memory-retrieval account, then during the production of the sentence, the head noun has to be activated, and kept adequately activated after production until it is time to inflect the verb. For this, as we outlined in the preceding text, WM is needed.

However, the mismatching plural local noun needs to be activated for production as well. Because its activation at the time of the verb is arguably higher than that of the head noun due to recency, then— every other relevant cue being equal—the local noun needs to be inhibited, to prevent it from being retrieved as the agreement controller for the verb. Here, we propose that inhibitory control influences how likely the verb is attracted to the number of the local noun; just as working memory influences how likely it is that the head noun is selected as agreement controller.

Current Experiment

Typically, attraction studies have used a version of the preamble completion paradigm (Bock & Miller, 1991; Brehm & Bock, 2013; Staub, 2009; but see Gillespie & Pearlmutter, 2011a; Haskell & Macdonald, 2005; Veenstra, Acheson, & Meyer, 2014, and Veenstra et al., 2015, for alternative production tasks). In most of these preamble completion paradigms, participants are presented with a subject phrase (auditorily, or in writing), which they have to repeat and complete by adding an inflected verb phrase. This paradigm allows experimenters to exert full control over the properties of the subject phrase and has been very productive when it comes to studying the effect of each of these properties on the agreement process. The downside of the paradigm is that it has a comprehension component: the given subject phrase needs to be decoded first, kept in memory, and finally reproduced. It is possible that the WM effect might be inherently connected to the paradigm. Note that Bock and Cutting (1992) found their participants' speaking span to correlate with repetition errors on all three experiments, whereas speaking span only correlated with attraction errors in one experiment. In addition, Hartsuiker and Barkhuysen (2006), and Slevc and Martin (2016) also employed the preamble completion paradigm. We avoid this confound by using a fairly novel picture description task, where participants describe pictures with complex subject phrases. No linguistic decoding or repetition is necessary, therefore, if there is any effect of WM it is more likely to be ascribed to the agreement process itself.

The present experiment investigates whether variability in WM and inhibitory control explains susceptibility to agreement attraction in neuro-typical speakers. To increase variability in executive control, we tested monolingual, bilingual, and bidialectal children. First, we tested children because their agreement production may not be as fully automatized as it is in adults, thus leading to greater variability in attraction error rates. Second, executive control has been found to vary between monolinguals and bilinguals. Bilingual children have been found to outperform monolinguals on WM tasks (Blom, Küntay, Messer, Verhagen, & Leseman, 2014; Morales, Calvo, & Bialystok, 2013), inhibitory control tasks and switching tasks (Bialystok, 1999; Bialystok & Martin, 2004; Prior & MacWhinney, 2010). Data from bidialectals (speakers who speak two varieties of the same language) is sparse but seems to suggest that they too have an advantage over monolinguals (Antoniou, Grohmann, Kambanaros, & Katsos, 2016, but see Ross & Melinger, 2017). It is not the aim of this article to investigate the bilingual advantage, and we are aware that several studies have not found any differences (Antón et al., 2014; Engel de Abreu, 2011; Paap & Greenberg, 2013). Instead, the selection

of different language backgrounds was meant as an attempt to increase the variability of cognitive skills in our participants.

Method

Participants

One hundred fifty children participated in the study. Twelve children were considered at risk for having language- or developmental problems or fell outside of the target age range of 10 to 12 years, and their data were discarded from the analysis. Ethical approval was given by the ethical board of the Université Libre de Bruxelles and informed consent was obtained from the children's parents before the study. None of the remaining 138 children's parents reported language or developmental problems for their children. 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 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). Forty-six children were bidialectal speakers who spoke exclusively West Flemish at home and Dutch in school, recruited in Ypres and Courtrai, West Flanders, Belgium (mean age = 11.4, SD = 9 months; 23 girls). West Flemish is a distinct dialect of Dutch that is widely spoken in the western part of Belgian Flanders (Devos & Vandekerckhove, 2005). Dutch, French, and West Flemish have similar rules for the computation of subject–verb number agreement. The bilingual and bidialectal speakers started learning Dutch upon entering the educational system at age 2.6.

The parents filled out a language background questionnaire (adapted from the Alberta Language Environment Questionnaire (ALEQ); Paradis, 2011), to ensure that all children had parents who both exclusively spoke the home language at home. The questionnaire also contained a section to determine socioeconomic status (SES) on the basis of the Family Affluence Scale (FAS; Boyce & Dallago, 2004) and levels of parental education. The parents of the bidialectal children also received a section in which they had to name pictures in West-Flemish, to check for proficiency in the dialect (adapted from Soete, 2013).

Materials and Procedure

The children were individually tested in Dutch in a quiet room in their school by one or two experimenters. The test battery was divided into three testing sessions, which took approximately 45 min each. There were 11 tasks in total, of which six were part of a different study investigating the comprehension of pragmatics. Sessions typically took place a few days apart.

Picture description agreement task. We adapted the picture description task from Veenstra, Acheson, and Meyer (2014), which is 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) × 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 negli-

(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, whereas the other one matched it in shape. Depending on the cue at the top of the screen (two green splashes for color, two white squares for shape), participants had to select the small object that matched in color or shape with the large object by pressing the left or right button. There were four blocks of items. In two of them all trials had to be matched by the same criterion (either all by shape or all by color). In the other two blocks, the shape and color criteria were mixed across trials. The difference in response times between the switching and nonswitching trials in mixed blocks represents the participants' switch cost. Higher values represent higher switch cost, thus weaker inhibition.

Attentional networks task. This task is meant to measure three aspects of attention: orienting, alerting, and executive control, as proposed by Posner and Petersen (1990). We used the child-friendly version from Rueda et al. (2004) and focused on the inhibition (executive control) aspect. In the relevant (flanker) condition, the participants saw five fish on the computer screen and had to press the left button if the middle fish was swimming to the left and the right button if the middle fish was swimming to the right. Trials were congruent (when all fish swam toward the same direction) or incongruent (when the middle fish swam toward a different direction than the flanker fish). The difference in response time between congruent and incongruent trials was the interference score. Higher values represent stronger interference, thus weaker inhibition.

Vocabulary size. Receptive vocabulary was tested with the Dutch version of the Peabody Picture Vocabulary Test (PPVT-III-NL; Dunn, Dunn, & Schlichting, 2005). The children saw four pictures on a page and had to point out the picture that matched the word the experimenter read out. Answers were correct or incorrect, and scores depended on the number of correct answers before the task was terminated as a result of reaching the error limit in a block (eight items incorrect in a block of 12 items). Productive vocabulary was tested with the Word Definitions task from the CELF 4-NL (Kort et al., 2008). Here, the experimenter read out a sentence which contained a word for which the child had to provide a definition. Depending on the quality of the definition, each trial could yield a score of zero to two points, with a maximum total of 50 points.

Analyses

A principal component analysis was performed on the scores from the executive control tasks, and composite scores were computed on the basis of the clusters from this analysis. Group differences were analyzed with between-group analyses of covariance (ANCOVAs). Bonferroni corrections were applied where necessary.

To allow for comparison with previous studies, the attraction error rates were analyzed with linear mixed effects regression (LMER) models in R, using a logistic linking function (Jaeger, 2008; R Development Core Team, 2015). Fixed factors were mismatch, head noun number, and their interaction. Random intercepts were included for subjects and items, as well as by-subject and by-items random slopes for head noun number, mismatch, and

their interaction (Barr, Levy, Scheepers, & Tily, 2013; Bates, 2005).

For the consecutive analyses, an attraction score was calculated for each participant on the basis of the percentage of errors in the mismatching conditions (out of the valid trials). We predicted attraction scores with multiple linear regression analyses. The first regression looked at the effect of the control variables on the attraction scores. Factors included language group, SES, vocabulary size, and age (in months). For all regressions we used backward elimination to get to the best model. Only SES contributed significantly to the models, therefore this factor was included in the following analyses. The second regression looked at the effect of the composite scores (verbal WM, nonverbal WM, and inhibition) on attraction rates.

Results

Preliminary Analyses

Principal component analysis (PCA). A PCA was conducted on the six executive control measures (scores in the forward and backward version of the digit span task, scores in the backward and forward version of the Corsi blocks task, interference effect from the Attentional Networks Task (ANT), and switch cost from the color–shape task) with direct oblimin rotation. This analysis returned three components with an eigenvalue above 1. The three factors combined explained 64.2% of the variance. Table 2 summarizes the PCA results including the factor loadings after rotation. As anticipated, participants' scores in the forward and backward conditions of the Corsi blocks task clustered on the first component, which we interpreted as representing the nonverbal WM aspect of executive control. Scores in the forward and backward version of the digit span task loaded on the second component, which we interpreted as representing the verbal WM component of executive control. Finally, the interference effect and switch cost loaded on the third component, which we interpreted as representing the Inhibition component of the executive control construct.

Composite scores. The following composite scores were computed on the basis of the PCA (individual measures are given in parentheses): verbal WM (scores in the forward and backward conditions of the digit span task), nonverbal WM (scores in the

Table 2

Summary of the PCA Including the Six Executive Control Measures

	Rotated factor loadings		
Measure	Factor 1: Nonverbal W	Factor 2: Verbal WM	Factor 3: Inhibition
Corsi blocks forward	**.803**	−.005	−.078
Corsi blocks backward	**.799**	−.116	.057
Digit span forward	.316	**−.640**	−.119
Digit span backward	−.054	**−.890**	.129
Switch cost	−.158	−.174	**.902**
Interference effect	.274	.233	**.464**
Eigenvalues	1.7	1.1	1.03
% of variance	28.7	18.4	17.2

Note. Factor loadings above .40 appear in bold.

forward and backward versions of the Corsi blocks task), and inhibition (switch cost from the color–shape task and interference effect from the ANT.[3] Before computing the inhibition score, the interference effect and switch cost scores were reverse-scored by multiplying by −1, so that for all measures a higher score indicated better performance. We also used composite scores for vocabulary size and SES. Vocabulary size was computed on the basis of children's scores in the PPVT and the word definitions task, whereas the SES composite score was calculated on the basis of maternal level of education, paternal level of education, and the FAS score. The composite scores were computed by transforming the individual measures into z scores (because the constituting variables were in different scales) and then averaging the relevant measures (see Antoniou et al., 2016; Calvo & Bialystok, 2014; Carlson & Meltzoff, 2008). We did this because when multiple measures of a cognitive component are extracted from different tasks and these measures show some degree of convergent validity and are combined into a single indicator of that component, specific task effects are averaged out and general variance increases. This leaves a less biased, more stable, more reliable, and purer estimator of the relevant component (Rushton, Brainerd, & Pressley, 1983) and achieves "more psychometric precision" (Carlson, 2003, p. 142).

Group differences in background measures. Monolingual, bilingual, and bidialectal children did not statistically differ in gender, $F(2, 135) = 0.363$, $p > .05$. Nevertheless, there were significant differences in age in months, $F(2, 135) = 3.625$, $p < .05$, SES, $F(2, 135) = 80.56$, $p < .05$, and vocabulary size, $F(2, 135) = 9.316$, $p < .05$. Regarding age, bidialectal children were marginally older than both bilingual ($p = .06$) and monolingual children ($p = .07$). In terms of SES, bilingual children had a higher SES than both bidialectal and monolingual children and monolingual children had a higher SES than bidialectal children (all $ps < .05$). Regarding vocabulary size, monolingual children had a significantly higher score than both bidialectal and bilingual children (all $ps < .05$).

Group differences in composite Executive Control scores. An ANCOVA with executive control as a within-subjects factor (inhibition vs. verbal WM vs. nonverbal WM), group as a between-subjects factor (monolinguals vs. bidialectals vs. bilinguals) and age, SES, and vocabulary size as covariates revealed no significant differences between the three groups (for the effect of language group: $F[2, 132] = 1.229$, $p > .05$ and for the Language Group × Executive Control interaction: $F[4, 264] = 1.801$, $p > .05$).

Agreement Attraction

The agreement task. The internal consistency of the agreement production task was tested with a split-half reliability. Attraction error rates were calculated for all odd and all even trials, resulting in a strong Spearman correlation of .67 ($p < .001$).

The agreement task yielded 9,936 observations. 863 of those observations contained one or more errors that were not verb errors (8.7%, with in total 273 incorrect head nouns, 13 incorrect prepositions, 237 incorrect local nouns, and 376 incorrect colors). For obvious reasons, when the participant incorrectly produced a plural head noun instead of a singular head noun, the plural verb that followed cannot be interpreted as an attraction error. These trials
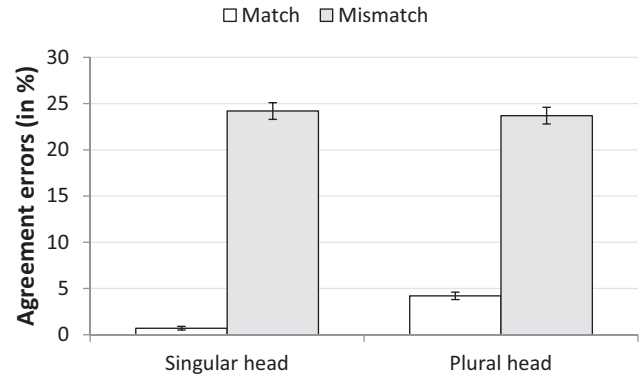
Figure 1. Agreement errors across the four experimental conditions. Error bars represent the standard error (*SE*) across all participants' ($n = 138$) mean.

were removed, leaving 9,073 observations for analysis. Agreement errors were made in 1,178 trials (13%). Most agreement errors occurred in the conditions where the number of the head noun mismatched with the number of the local noun (see Figure 1). We refer to agreement errors on mismatching trials as *attraction errors*.

The LMER model included mismatch, head noun number and their interaction for comparison with agreement patterns from the literature (see Table 3). The model showed that there was a main effect of mismatch, with more errors made when the numbers mismatched than when they matched. There was also a main effect of head noun number, with more errors on trials with a plural head noun than with a singular head. head noun number and mismatch interacted, because the mismatch effect was stronger for the singular head nouns ($\beta = 2.24$, $SE = 0.20$, $z = 11.47$, $p < .001$) than for the plural head nouns ($\beta = 1.40$, $SE = 0.12$, $z = 12$, $p < .001$).

Predicting attraction by language group. The second analysis focused on the potential group differences in attraction error rates and other potentially confounding factors. We used the proportion of errors in the mismatching conditions as a score of agreement attraction. A linear regression showed that there were no group differences in attraction (see Table 4), even though visual inspection of the plot suggests there might be, see Figure 2. There were also no effects of age or vocabulary size. Attraction errors were predicted by SES, which in turn was highly correlated with language group ($\rho = .732$; $p < .001$).

Predicting attraction by composite scores. The third analysis focused on attraction errors and whether they are predicted by the composite scores of the executive function constructs. A linear regression showed that both verbal WM and inhibition affected attraction error rates (see Table 5). Children with higher verbal WM produced fewer attraction errors, whereas children who experienced more interference produced more attraction errors. Im-

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[3] We chose to use the z-composite scores, rather than the PCA loadings, because the composite method extends to all individual differences (ID) measures, including vocabulary size and SES, and because there is evidence to suggest the z composite scores provide the more valid measure of the target cognitive component (see, e.g., Carlson and Meltzoff (2008); Cuevas et al., (2014); Meuwissen and Carlson (2015) for a similar approach).

Table 3
Summary of the Linear Mixed Effects Regression Model Predicting Agreement Errors

Variable	Coefficient	SE	z value	Pr(>|z|)	Random slope
(Intercept)	−3.249	.129	−25.290	<.001	Subjects, items
Mismatch	1.830	.120	15.242	<.001	Subjects, items
Head Noun Number	.434	.131	3.318	<.001	Subjects, items
Head Noun Number × Mismatch	−.438	.113	−3.889	<.001	Subjects, items

portantly, the two factors, verbal WM and inhibition, were not correlated ($r = -.051$; $p = .55$). In addition, children with a higher SES produced fewer errors than those with a lower SES.

Discussion

In this article, we hypothesize that both WM and inhibitory control are aspects of individual differences in executive control that are associated with rates of attraction errors in agreement in production. We use the agreement production paradigm recently developed by Veenstra and colleagues (Veenstra et al., 2014), which minimizes demands on comprehension and working memory. Regression analyses revealed that higher composite scores of WM and inhibitory control were associated with fewer attraction errors. In the following text, we discuss a number of implications of the findings.

Validation of a Novel Agreement Task

To investigate the role of executive control during the production of subject–verb agreement, we used a picture description task. Although attraction has traditionally been studied with preamble completion tasks, the picture description paradigm has some advantages. For one, in this picture description task the comprehension component (inherent to the preamble completion paradigm) is limited: Participants generate a full sentence on the basis of pictures, rather than on linguistically provided subject phrases that have to be decoded first.

Another advantage is its suitability for use with children: whereas young children may have limited reading skills or working memory which might influence the decoding and repetition of a preamble (and possibly the following verb inflection), these skills are less important in a picture description task. Reducing the WM load of the task also means that effects of WM are more likely to be explained by the process under investigation rather than by the paradigm used. The attraction patterns we found here in children are very similar to the patterns found in adults (Veenstra et al., 2014), which suggests that the task is appropriate for children as well.

Finally, the items in the current picture description task had very low semantic content: only the head and local nouns were varied and the pictures depicting them consisted of only three different, simple shapes (circle, star, and triangle), which children are assumed to be familiar with from a very young age. Indeed, vocabulary size did not influence the performance on the agreement task when entered as a factor in the analyses.

Executive Control During Agreement Production

Previous studies reporting effects of WM on agreement all used the preamble completion paradigm. As discussed in the preceding text, this paradigm relies heavily on WM because of the repetition part, where participants read or hear a subject phrase which they have to repeat verbally. One question we sought to address with the current picture description task is whether WM effects are still present when the repetition component is removed. Analysis of the composite scores for verbal WM (digit span scores) and nonverbal WM (Corsi blocks scores), showed an effect of verbal WM only: Higher verbal WM scores were related to lower attraction error rates. This suggests that even in a more natural agreement production task, WM is needed.

There was also a novel effect of inhibition: a higher composite score for Inhibition (higher switch cost and more interference in the ANT flanker task) was related to higher attraction error rates. The subject phrases in the agreement experiment consisted of matching and mismatching local nouns. The results suggest that the distraction from a mismatching local noun has to be inhibited in order to produce correct agreement.

Table 4
Summary of the Multiple Regression Model Predicting Attraction Rates by the Control Variables

Model	Unstandardized		Standardized		
	B	SE	β	t	p
1 (Constant)	40.036	24.963		1.604	.111
Group	−3.606	3.364	−.180	−1.525	.130
Age	−.062	.180	−.029	−.346	.730
Vocabulary	−1.395	1.641	−.070	−.850	.397
SES	−4.018	2.320	−.206	−1.732	.086
4 (Constant)	24.457	1.332		18.367	.000
SES	−6.618	1.570	−.340	−4.215	**.000**

Note. Model 1 is the initial model; Model 4 is the final model. Significant factors appear in bold. SES = socioeconomic status.
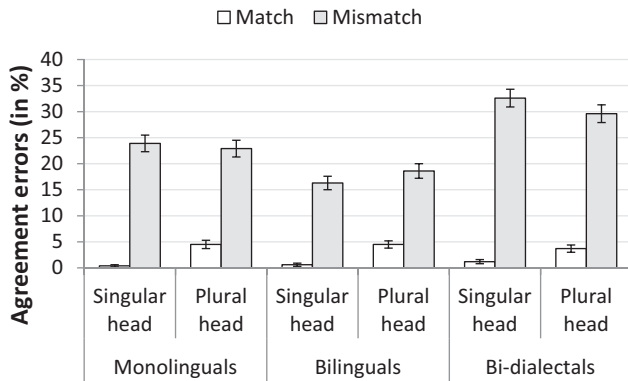
Figure 2. Agreement errors across the language groups. Error bars represent the standard error (*SE*) across participants.

Figure 3. Activation of number features during production of the sentence "The bowl with the stripes is broken." Note that the number of the head noun (*bowl*, singular) is a mismatch with the number of the local noun (*stripes*, plural) and that activation decays over time.

We proposed that in agreement production, WM is needed to maintain the activation of the head noun number after its production (or, properly encode the necessary retrieval cues). A speaker with a low WM would be less successful in doing so. When the agreement controller has to be retrieved from a collection of multiple active elements, and the head noun is not sufficiently active, this will become more difficult and vulnerable to attraction. At the same time, a very recently activated local noun can compete with the head noun for retrieval as agreement controller. Inhibitory control is then needed to prevent the local noun from taking over control. See Figure 3 for a schematic representation. This proposal is in line with memory-retrieval models of language production (Badecker & Kuminiak, 2007; Thornton & MacDonald, 2003). It is not clear that it is compatible with forward-looking memory-encoding models (Gillespie & Pearlmutter, 2011b, 2013; Solomon & Pearlmutter, 2004).

On grounds of parsimony, one advantage of the proposed memory-retrieval account is that it is not limited to explaining attraction patterns, whereas the hierarchical feature passing, marking and morphing, and scope of planning accounts are. The memory-retrieval account also allows parallels to be drawn with comprehension. Lewis and Vasishth (2005) proposed a similar model for sentence comprehension, based on memory retrievals,

"modulated by similarity-based interferences and the fluctuation of memory trace activation" (Lewis & Vasishth, 2005, p. 376; see also Arnett & Wagers, 2017). This comprehension version of the memory retrieval-model can account for attraction phenomena in comprehension: readers are less likely to notice agreement errors when the verb matches with a local noun instead of the head noun (Pearlmutter et al., 1999; Tanner et al., 2014).

The results of the current experiment showed independent effects of verbal WM and inhibition, which is in line with our proposal. In terms of the cognitive processing principles in the memory retrieval account (Lewis & Vasishth, 2005: 380), verbal WM conceivably affects principles A2 and A3: the activation of the different chunks of information available for processing (in our case, the number of a head noun to copy for agreement) and the decay of activation from usage history and time (in our case, the relative recency of the head and local nouns). Inhibition skills affect the retrieval process, principle A4, in which the effectiveness of a cue (in our case, a noun to agree with in number) is reduced as the number of items associated with that cue increases (so, having a local noun in addition to the head noun). In the current study, the effect of WM was stronger than that of Inhibition, but it is unclear how poor a speaker's WM or inhibition has to be to actually produce an attraction error. Relatedly, as inhibition and verbal WM scores were not correlated, it would be interesting to investigate

Table 5
Summary of the Multiple Regression Model Predicting Attraction Rates by the Composite Scores

Model	Unstandardized		Standardized		
	B	SE	β	t	p
1 (Constant)	24.553	1.275		19.259	.000
SES	−5.416	1.601	−.278	−3.382	**.001**
Inhibition	−4.489	1.772	−.196	−2.533	**.012**
Verbal WM	−4.838	1.663	−.238	−2.909	**.004**
Nonverbal WM	−.739	1.575	−.038	−.470	.639
2 (Constant)	24.546	1.271		19.311	**.000**
SES	−5.555	1.569	−.285	−3.540	**.001**
Inhibition	−4.510	1.766	−.197	−2.554	**.012**
Verbal WM	−4.978	1.632	−.245	−3.050	**.003**

Note. Model 1 is the initial model; Model 2 is the final model. Significant factors appear in bold. SES = socioeconomic status.
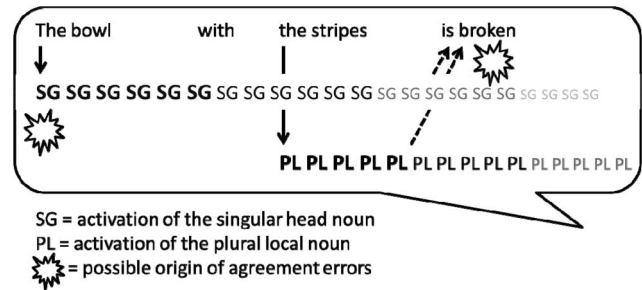
whether speakers with poor WM can compensate the poor head noun activation with strong inhibition skills, and, vice versa, whether speakers with poor inhibitory control can prevent attraction errors with a strong WM. We leave this for further research.

Singular Attraction

Many studies have argued that attraction from a singular local noun is very unlikely (Eberhard, 1997). Nevertheless, we included conditions with plural head nouns combined with matching plural local nouns and mismatching singular local nouns. In the first analysis, where we only looked at the conditions of the agreement task (head noun number and number mismatch), there was an attraction asymmetry in the sense that the attraction effect was stronger for singular head nouns combined with plural local nouns, compared with plural head nouns combined with singular local nouns. Importantly, however, the attraction effect was still significant for the latter combination. The asymmetry stemmed from a rise in baseline (error rate in the matching condition), rather than a drop in attraction (error rate in the mismatching condition) in the plural head noun sentences. This raised plural baseline can be explained when one considers singular as a default (Bock & Eberhard, 1993). When a participant loses track of the subject in the singular condition and resorts to a default singular, no error is visible. However, when a participant is confused in the plural condition and resorts to a default singular, this presents itself as an attraction error. Whereas other studies have also reported higher error rates for matching plural nouns compared with matching singular nouns (Bock & Cutting, 1992; Bock & Miller, 1991; Franck et al., 2002, Experiment 2; Vigliocco et al., 1995; Veenstra et al., 2014), this was often paired with smaller attraction effects for plural compared with singular heads in the mismatching conditions. In contrast, our results suggest that attraction can be equally strong for singular and plural head noun sentences.

Eberhard (1997) argued that the asymmetry in attraction stems from the idea that nouns are marked for number. An unmarked noun is the singular default, whereas a plural marking makes it plural. In the case of attraction, the number specification of an unmarked singular head noun can be overridden by a marked plural feature from a plural local noun. However, the number specification of a marked plural head noun cannot be overridden by an empty unmarked singular local noun. The marking and morphing model accounts for this by assigning singulars a value of zero and plurals a value of one. Adding one to zero, turns the zero into one, but adding zero to one does not turn the one into zero (Eberhard et al., 2005). Badecker and Kuminiak (2007) proposed that the gender asymmetry they found in their study is explained by interference that is modulated by the relative markedness of the head and local noun gender. If extended to noun number, this would also predict singular/plural asymmetries. However, the authors also point out that markedness is just one of many cues used to retrieve an agreement controller. Findings that show that singulars can exert attraction are therefore problematic for the marking and morphing model, but less so for memory retrieval accounts and the grammatical hierarchical feature passing and the scope of planning accounts.

Before we conclude our evaluation of the two types of accounts, we acknowledge that effects of WM found in the present study are not necessarily incompatible with the grammatical accounts we described before. If we assume that spread-

ing activation needs some sort of WM resources, it is possible to adapt the hierarchical feature passing account and the marking and morphing to explain individual differences. However, until and unless such an adaptation is proposed in a clear way, it is fair to conclude that though the present findings are compatible with a cue-based memory retrieval account, this cannot be said for grammatical accounts yet. Moreover, on the basis of evidence from our study and the previous literature, our evaluation is that agreement attraction is very likely to be best explained with a cue-based memory retrieval account. Such an account can deal with both grammatical and conceptual cues, which the hierarchical feature passing account cannot. It can account for patterns found in both production and comprehension, whereas the hierarchical feature passing, marking and morphing, and the scope of planning account are explicitly dealing with production. Furthermore, cue-based retrieval allows for attraction promoted by "unmarked" singulars, which is impossible on the marking and morphing account. Cue-based memory retrieval offers the most comprehensive account of agreement production errors specifically and linguistic relations in general. However, further research, both conceptual and empirical, is needed to reach solid conclusions on this issue.

Executive Control in Monolinguals, Bilinguals, and Bidialectals

Previous research has reported a bilingual advantage where bilingual children outperform monolingual children on several executive control tasks. In the current study, however, we did not find any differences between the performance of monolinguals, bilinguals, and bidialectals on the executive control measures. There are at least three reasons why this might be the case. Perhaps the language situation of the children in this study did not provide enough opportunities for language switching, which has been proposed as the key aspect of the bilingual experience that leads to gains in executive control (Prior & Gollan, 2011). Additionally, our participants may not have been balanced bilinguals. Language balance may modulate the bilingual advantage, as shown by Bosma, Blom, and Versloot (2017) who found that speakers who were equally proficient in their two languages performed better on selective attention and verbal WM tasks than speakers who were dominant in one of their languages (for similar claims, see Crivello et al., 2016; Videsott, Della Rosa, Wiater, Franceschini, & Abutalebi, 2012).

Finally, a growing number of recently published studies propose that there is no advantage for any kind of bilingual speakers (e.g., Anton et al., 2014; Duñabeitia et al., 2014; Engel de Abreu, 2011; Paap & Greenberg, 2013; Paap, Johnson, & Sawi, 2014; Ross & Melinger, 2017). It is beyond the scope of this article to enter in this debate, as we did not set out to investigate group differences. Here, we used language background as a feature of the population that had the potential to introduce variability in executive control.

We did, however, find differences in vocabulary size, in line with other bilingualism studies (Bialystok, Luk, Peets, & Yang, 2010; Oller, Pearson, & Cobo-Lewis, 2007). We only tested vocabulary in Dutch, and scores for receptive and productive vocabulary were lower for bilinguals and bidialectals compared with monolinguals. This effect is related to the fact that for the bilinguals and bidialectals, vocabulary input is distributed across more than one language/variety, and studies looking at overall vocabulary size (including both lan-

guages) often find no differences between bilinguals and monolinguals, or sometimes bigger vocabularies for bilinguals (Pearson, Fernandez, & Oller, 1993). Note, however, that we tested receptive vocabulary with the PPVT, which is standardized for a monolingual population (Dunn et al., 2005). Looking at the standardized scores, both bilingual and bidialectal groups scored, on average, within the monolingual norm, even though their scores were lower than the monolinguals in the current study.

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Appendix

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Table A1

List of Head Nouns, Prepositions, Local Nouns, Verbs, and Color Adjectives That Are Combined in the Creation of the Target Utterances of the Picture Description Agreement Task

Language	Head noun	Preposition	Local noun	Verb	Color
Dutch	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
English	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 parentheses.