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GRAMMATICAL ATTRACTION ERROR DETECTION IN CHILDREN AND ADOLESCENTS

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ABSTRACT

Children and adolescents often make grammatical errors in sentences such as saying "the friend of our neighbors smile" instead of "the friend of our neighbor smiles". Recent research suggests that these attraction errors arise because they fail to inhibit an automated but inappropriate heuristic strategy that makes them blindly agree the verb with the immediately preceding word. However, it is unclear whether these errors predominantly result from a failure to complete the inhibition or from a failure to detect that the strategy is erroneous and needs to be inhibited in the first place. The present study focuses on a test of the critical error detection sensitivity issue. Children and adolescents were asked to solve grammatical problems and indicated their response confidence. Adolescents showed a clear confidence decrease after having committed an attraction error which was less pronounced in the group of children. This indicates that although children might not detect the inappropriate nature of their answer, adolescents have a better grammatical understanding than their errors seem to suggest.

Teaching children to write properly without grammatical mistakes is one of the primary goals of the elementary and secondary school curriculum. A key grammatical ability that children need to master in this respect is learning how to inflect verbs to agree with the number of the subject (singular vs plural) in a sentence (Beers, & Beers, 1992; Fayol et al., 1999; Frisson, & Sandra, 2002; Kemp, & Bryant, 2003; Largy, 2001; Nunes, Bryant, & Bindman, 1997a Nunes, Bryant, & Bindman, 1997b; Totereau, Thevenin, & Fayol, 1997). For example, children need to learn that we write "*the cat comes*" but "*the cats come*". By the fifth grade, children have largely automatized the verb inflection rule (Fayol, Hupet, & Largy, 1999) and no longer make errors when they have to use plural inflections in simple cases of subject-verb agreement. However, children, adolescents, and sometimes even adults continue to make systematic verb inflection errors in more complex linguistic contexts in print and speech (Bock, 1995; Bock & Cutting, 1992; Bock & Eberhard, 1993; Bock & Miller, 1991; Nunes, Bryant, & Bindman, 1997c; Vigliocco, Butterworth, & Semenza, 1996). For example, in languages such as English and French, verb inflection errors typically occur in so-called noun phrases of the type "Noun 1 + Noun 2 + Verb" (e.g., "*the friend of the neighbors smile*" instead of "*the friend of the neighbors smiles*") because one makes the verb agree with the immediately preceding noun ("*neighbors*") especially when this noun is in its plural form (Bock, 1995; Bock & Cutting, 1992; Bock & Eberhard, 1993; Bock & Miller, 1991; Fayol et al., 1994; Fayol et al., 1999 Largy et al., 1996). In French similar verb

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inflection errors can also be observed in sentences of the type "Singular subject pronoun + Plural pronoun + Verb" (e.g., "*Il les mange*" in English *"He eats them"*). In French the plural pronoun (e.g., *"les"*) is placed before the verb ("*mange*") and consequently participants can be tempted to make the verb agree with the preceding plural pronoun ("*les*") instead of the singular subject of the sentence (e.g., Chanquoy & Negro, 1996; Fayol et al., 1994; Hupet, Fayol, & Schelstraete 1998; Largy, Dédéyan, & Hupet, 2004; Largy, Fayol, & Lemaire 1996).

The inflection errors in complex linguistic context in which the verb is erroneously made to agree with the preceding noun or pronoun are known as "attraction" errors (Bock & Miller, 1991). These attraction errors have been shown to result from the automatization of *the verb* inflection rules in simple contexts (Fayol et al., 1999; Lanoë et al., 2016). That is, when children enter elementary school they learn that certain marks are frequently associated with plurality. For example, in English and French plural nouns (and pronouns in French) are inflected with − s (e.g., "the book" but "two books", in French "le livre" and "les livres"). Through repeated exposure children will learn to use this plurality marker to use the plural verbal inflection. Over time this will develop into an automated strategy or heuristic to quickly and effortlessly determine the inflection of the verb (e.g., "use plural inflection of the verb after plurality marker − s"). This heuristic works well in most linguistic contexts. It will help writers arrive at the correct spelling in simple sentences such as "the cat runs" and "the plants grow". However, blindly applying it in complex contexts such as the "Noun 1 + Noun 2 + Verb" or "Singular subject pronoun + Plural pronoun + Verb" will lead to attraction errors.

Given the early automatization of verb inflection rules, Lanoë et al. [2016] recently suggested that attraction errors result from an executive failure to inhibit the automated heuristic strategy. There is indeed some evidence suggesting that both children and adults who score higher on general executive functioning tests (e.g., working memory or fluid intelligence tests) commit fewer attraction errors (Bock & Cutting, 1992; Hartsuiker & Barkhuysen, 2006; Veenstra et al., 2017). To directly validate their claim about the specific role of inhibitory processing, Lanoë et al. adopted a negative priming paradigm (Tipper, 1985).

The basic idea behind the negative priming paradigm is simple: if you inhibit a specific strategy on one trial, then activation of this same strategy on a subsequent trial should be hampered (Borst, Moutier, & Houdé, 2013). Simply put, when you block a strategy at Time 1, you will pay a price when trying to reactivate it again immediately afterwards. In their critical test items Lanoë et al. [2016] asked participants to evaluate the correctness of a simple sentence in which applying the automated *"use plural inflection after plurality marker − s"* strategy resulted in the correct response (e.g., *"The horses run*"). For completeness, note that Lanoë et al. tested French-speaking participants and focused on attraction errors with "Singular Subject + Plural Pronoun + Verb" sentences. To keep the exposition as accessible as possible for non-French speaking scientists we use English examples based on the related "Noun 1 + Noun 2 + Verb" case to illustrate the experimental rationale here.

Immediately before presentation of the critical test item, participants in (2016) study were presented with either an incongruent or congruent problem. In incongruent problems participants had to evaluate the correctness of a sentence in which applying the automated '*use plural inflection after plurality marker − s*" heuristic resulted in an attraction error and would need to be inhibited (e.*g., "The friend of our neighbors smile"*). In congruent problems, participants evaluated control sentences in which correct responding did not require inhibition of the heuristic (e.g., *"The friend of our neighbor smiles"*). Results showed that for children, adolescents, and adults responding to the simple test sentence took longer after participants had solved an incongruent problem than after they had solved a congruent problem. Hence, a typical negative priming effect was observed. Solving the incongruent problems in which correct responding required inhibiting the heuristic strategy, hampered activation of this same strategy on the subsequent trial, resulting in increased response times.

In general, accounts that have stressed the importance of inhibition in human cognition and development have received wide support and have become increasingly popular (e.g., Dempster & Brainerd, 1995; De Neys & Everaerts, 2008; De Neys & Van Gelder, 2008; Harnishfeger & Bjorklund, 1994; Houdé, 1997, 2007; Reyna et al., 2003; Simoneau & Markovits, 2003). The results of Lanoë et al. (2016) also directly underscore the role of inhibitory processing in avoiding grammatical attraction errors. However, the precise nature of the inhibition failure that results in an attraction error is still open to different interpretations. A key question is whether developing writers typically make attraction errors because they lack the executive resources to complete inhibiting the automated heuristic strategy or because they fail to detect that they need to inhibit the strategy in the first place.

To clarify the key point, it is important to stress that inhibitory accounts do not posit that people need to block heuristic strategies in all situations (e.g., Brainerd & Reyna, 2001; De Neys & Franssens, 2009 ; De Neys & Vanderputte, 2011 ; Houdé & Guichart, 2001; Jacobs & Klaczynski, 2002; Klaczynski et al., 2001; Stanovich, West, & Toplak, 2011). In many situations automatized heuristic strategies can provide us with correct problem solutions. The automatization is highly beneficial in these cases because it allows us to decide fast without a need to engage in extensive deliberation (Kahneman, 2011). As we noted, when deciding on verb inflection, for example, the heuristic *"use plural inflection after plurality marker − s"* is useful in most linguistic contexts. The problem is simply that in some contexts it will conflict with the correct grammatical rule and needs to be avoided in these specific cases. Hence, inhibitory accounts typically postulate some kind of elementary monitoring process that signals whether the use of the heuristic is appropriate or not (De Neys, Lubin, & Houdé, 2014; Reyna et al., 2003; De Neys & Glumicic, 2008; Evans and Stanovich, 2013; Pennycook, Fugelsang, & Koehler, 2015; Simon, Lubin, Houdé, & De Neys, 2015). This implies that an efficient inhibition requires that one monitors for attraction errors first and inhibits the heuristic strategy whenever it is detected. Hence, what we need to know is whether developing individuals who commit an attraction error mainly fail at this initial monitoring stage or at the subsequent inhibition per se. Unfortunately, the efficiency of the attraction error monitoring or detection process has not been examined. The present study starts to address this shortcoming and presents a first direct test of the attraction error sensitivity question.

To answer our research question we presented participants in the preadolescent to adolescent age range with the congruent and incongruent verb inflection problems that were introduced by Lanoë et al. (2016) . To recap, in incongruent problems, applying the "use *plural inflection after plurality marker −s"* heuristic will result in an attraction error and needs to be inhibited (e.g., "*The friend of our neighbors smiles"*). In congruent problems, using the heuristic will not result in an attraction error and there is consequently no need to inhibit it (e.g., "*The friend of our neighbor smiles"*). After solving each problem participants were asked to indicate their response confidence on a rating scale. Research on heuristic error monitoring in the reasoning and decision making field often uses such confidence ratings to measure people's error detection sensitivity (e.g., De Neys & Feremans, 2013; De Neys et al., 2013; Stupple, Ball, & Ellis, 2013; Pennycook, Trippas, Handley, & Thompson, 2014; Thompson & Johnson, 2014). The basic rationale in the case of attraction error detection is straightforward. If an attraction error on incongruent problems results from a blind application of the heuristic strategy without taking into account whether it is appropriate in the linguistic context, participants will not have noticed that their answer is erroneous. Consequently, one's response confidence after solving incongruent problems (in which use of the heuristic results in an error) and congruent problems (in which use of the heuristic does not lead to an error) should not differ. However, if when making an attraction error, one has some minimal awareness of the inappropriate nature of their heuristic response, this should decrease one's confidence and result in lower confidence ratings after solving incongruent than after solving congruent problems.

We also wanted to explore potential developmental changes in attraction error detection. Influential work in the cognitive control field has linked basic error- and conflict monitoring to the Anterior Cingulate Cortex, a brain region in the medial prefrontal part of the brain (e.g., Botvinick, Cohen, & Carter, 2004; Brown, 2013; Ridderinkhof, Ullsperger, Crone, & Nieuwenhuis, 2004; Ullsperger, Fischer Nigbur, & Endrass, 2014; but see also Burle, Roger, Allain, Vidal, & Hasbroucq, 2008). Interestingly, this region demonstrates a late maturation and only reaches full functionality over the adolescent years (e.g., Davies, Segalowitz, & Gavin, 2004; Fitzgerald, Perkins, Angstadt, Johnson, Stern, & Welsh, 2010; Santesso & Segalowitz, 2008). In addition, the hypothesis with respect to possible age related changes in attraction error detection also receives some support from the literature on metacognition. Metacognition refers to cognitive activities that reflect on, monitor, or regulate first order cognition (Kuhn, 2000). Error monitoring clearly exhibits metacognitive aspects and developmental studies have shown that children's metacognitive skills improve substantially with age (e.g., Roderer & Roebers, 2010; Schneider, 2008). Hence, in theory it cannot be excluded that younger and older participants will show differential attraction error monitoring efficiency.

To explore this developmental hypothesis we decided to contrast the attraction error detection performance in a younger preadolescent and an older adolescent group. The group of preadolescents consisted of children from the final grades of elementary school (5th and 6th grade) and the older adolescent group were secondary school students (8th and 9th grade). We opted for this specific age range because attraction errors are most prevalent here. On one hand, younger children (before grade 5) have not yet automatized the verb inflection rules and rarely commit attraction errors per se. On the other hand, although adults sometimes still commit attraction errors they become increasingly rare by the end of secondary school (Fayol et al., 1999). To avoid confusion, precisely because of the lack of automatization younger children are more likely to commit verb inflection errors in simple contexts (e.g., the boy comes) but these are not the focus of the present investigation. Hence, focusing on the childhood-adolescent age range allowed us to study the critical developmental stage in which attraction errors are most common.

1. METHOD

1.1. Participants

A total of 95 preadolescent children (mean age 11.60 ± .65, range 10.67-13.08; 46 males and 49 females) and 61 adolescents (mean age: 14.51 ± .64 years, range 13.42-16; 30 males and 31 females) participated in the study. The children were recruited from the 5th and 6th grade of an elementary school in the Caen (France) region. Adolescents were recruited from the 8th and 9th grade of an associated secondary school. All the participants reported normal or corrected-to- normal vision. Participants were tested in accordance with national and international norms governing research on human participants. All parents or guardians gave informed consent for the study. All the participants were native French speakers and came from middle-class homes. The parents and teachers reported that none of the children or adolescents had any cognitive impairments or developmental problems.

Our initial aim was to recruit 100 participants in each age group based on prior developmental work on error detection with related methodology in the reasoning field (De Neys, Cromheeke, & Osman, 2011). However, because of participant recruitment difficulties in the adolescent age range we ended up with a smaller number of adolescents. For completeness, note that with an observed error rate of 55% and 78% respectively, our obtained sample sizes would suffice to detect an a priori moderate error detection effect (approximately Cohen d = .39) with power of .80 in the adolescent group and a small to moderate effect (approximately Cohen d = .28) in the younger group of children.

1.2. Material

Materials were based on the congruent and incongruent verb inflection problems that were introduced by Lanoë et al. (2016). As Lanoë et al. we tested our French participants with sentences of the type "Singular subject + (plural or singular) Pronoun + Verb". As we noted, in French the pronoun is placed before the verb. Therefore, congruent and incongruent problems can be constructed by manipulating the number (plural or singular) of the pronoun. In the incongruent problems the plural pronoun was used (e.g., "Je les sauve" or "I save them") whereas the singular pronoun was used in the congruent problems (e.g., "Je le sauve" or "I save it"). Because the subject is singular, the correct spelling for both congruent and incongruent problems is to use the singular inflection of the verb. Hence, for incongruent problems relying on the *"use plural inflection after plurality marker −s"* heuristic will result in an attraction

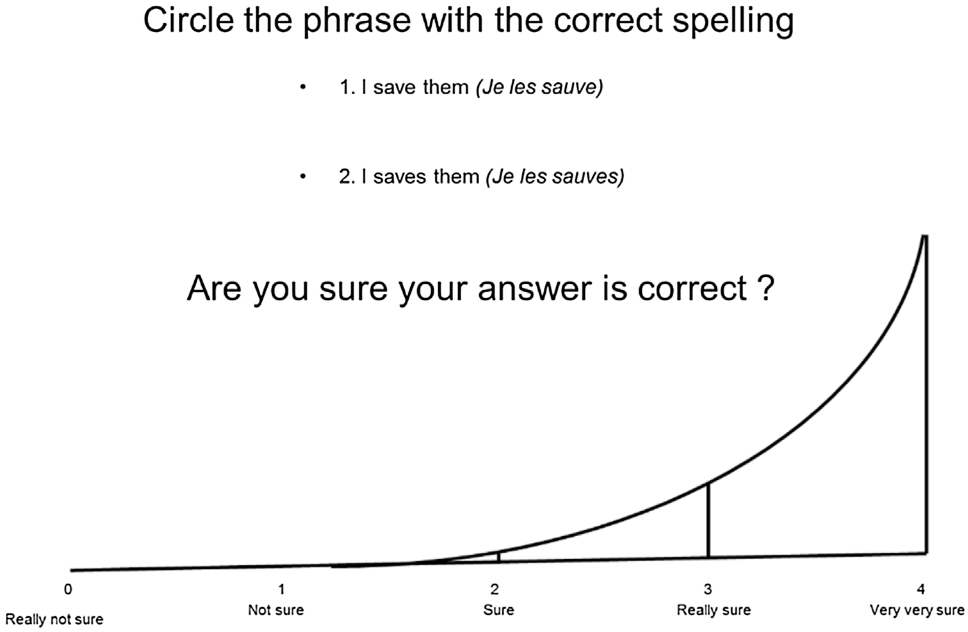

Fig. 1. An example of the item format with five-point confidence scale. Five gradients were used to represent the different levels of the scale that ranged from 0 ("really not sure") to 4 ("very very sure"). The participants had to circle the correct answer and the gradient of the scale that best reflected their feeling of confidence.

error because the preceding plural pronoun will trigger the plural verb inflection. On congruent problems relying on the heuristic will not result in an error because the preceding pronoun is singular and does not have the −s marker. Consequently, the correct singular verb inflection will be applied.

The previous work of Lanoë et al. (2016) indicated that children and adolescents show high error rates when solving the incongruent problems. Note that in theory one could try to vary the difficulty of the problems (and likelihood of attraction errors) by manipulating the problem content (e.g., by using homophone verbs − i.e., verbs that have same pronunciation as a possible noun − or by varying the plausibility of the phrase, e.g., Thornton & MacDonald, 2003). We decided against the use of such manipulations to avoid any confounding heuristic impact and/or possible inter-age group variance resulting from these factors.

Participants were presented with a booklet containing a total of 8 problems (4 congruent and 4 incongruent). Fig. 1 illustrates the problem format. Each problem consisted of two French sentences that were printed one above the other: the two sentences differed only by the verb inflection. One sentence had correct verb inflection, and one sentence had incorrect inflection. The position of the correct and incorrect sentences was counterbalanced throughout the booklet. Problems were presented in one of two (pseudo) randomly determined orders. We made sure that half of the booklets started with a congruent problem and that the same type of problem was not presented on more than two consecutive pages. A full overview of all the problems is presented in the Appendix. Participants circled the sentence which they believed to be correct. Under the two sentences participants found a 5-point rating scale (ranging from 0–"really not sure" to 4 "very very sure") and were asked to indicate their response confidence by circling the corresponding number.

1.3. Procedure

Participants were collectively tested during a regular course in their classroom. The experimenter explained to the children that they had to solve eight spelling problems and were to indicate their confidence by using a 5-point rating scale. The different levels of the scale were explained and the experiment gave some examples to check the scale understanding. Then booklets were distributed by the experimenter and participants solved the problems at their own pace.

2. RESULTS

2.1. Accuracy

For each participant we calculated the average performance on the incongruent and congruent problems and subjected these to a 2 (age, between-subjects) x 2 (congruency, within-subjects) mixed model ANOVA. As Fig. 2 indicates, results showed that there was a main effect of congruency, $F(1,154) = 357.15$, $p < .0001$, $\eta_p^2 = .70$. As expected, both age groups had little trouble solving the congruent problems correctly but struggled with the incongruent problems. Overall, our participants committed attraction errors on the vast majority of incongruent trials. There was also a main effect of age, $F(1,154) = 15.70$, $p = .0001$, $\eta_p^2 = .09$, and the age and congruency effects interacted, $F(1,154) = 8.58$, $p = .004$, $\eta_p^2 = .05$. Follow-up Newman-Keuls contrast tests showed that the

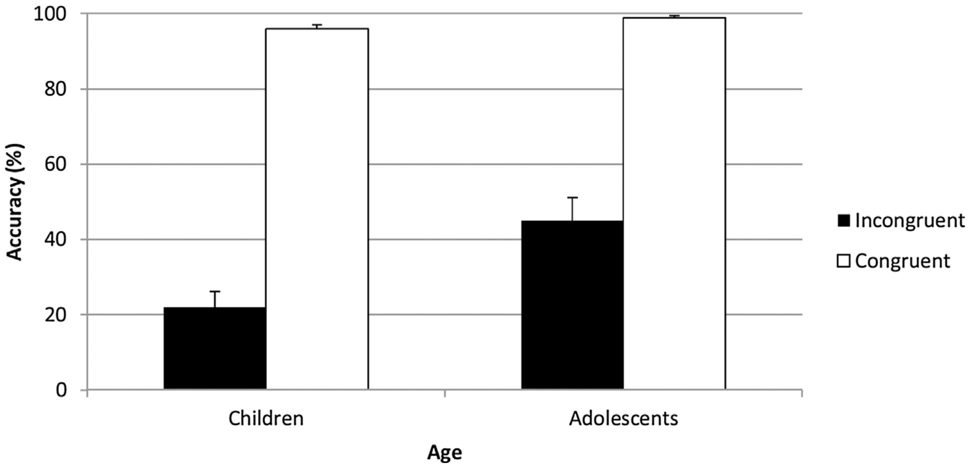

Fig. 2. Average response accuracy on congruent and incongruent problems in the two age groups. Error bars are standard errors.

accuracy on incongruent problems doubled from 22% for the youngest age group to 45% for the adolescents ($p < .0001$). Hence, in line with previous work there was a clear age-related decrease in attraction errors. Accuracy on the congruent problems was at ceiling and did not differ in both age groups ($p = .43$).

Obviously, given that our age range was selected because the *"use plural inflection after plurality marker −s"* strategy is believed to be fully automated at this developmental stage, the ceiling performance on the congruent problems across age is not surprising. By definition, use of the heuristic will result in the correct response on the congruent problems. However, the congruent problem performance does help to validate that participants' errors on the incongruent problems cannot be simply attributed to a general guessing confound. Clearly, if children erred because they were not motivated to participate and responded randomly, for example, their performance on the congruent problems should have been equally affected and would have been much lower.

2.2. Response confidence

The central question in our study concerned participant's response confidence. To test the attraction error detection sensitivity we were specifically interested in the confidence ratings for incorrectly solved incongruent problems (i.e., problems on which an attraction error was committed). The key contrast concerns the confidence ratings for erroneously solved incongruent problems and correctly solved congruent problems. To recap, applying the "*use plural inflection after plurality marker −s*" will result in a correct response on the congruent problems, but an incorrect response on the incongruent problems. If an attraction error on incongruent problems results from a blind application of the heuristic strategy without taking into account whether it is appropriate in the linguistic context, participants will not have detected that their answer is erroneous. Consequently, their response confidence after solving incongruent problems (in which use of the heuristic results in an error) incorrectly and congruent problems (in which use of the heuristic results in a correct response) correctly should not differ. Therefore, for each individual in each of our two age groups we calculated the average confidence rating for erroneous incongruent and correct congruent problem responses. These averages were subjected to a 2 (age, between-subjects) x 2 (congruency, within-subjects) mixed model ANOVA. Obviously, individuals who did not commit any attraction errors ($n = 25$) were not included in the analysis (total included $n = 121$; children $n = 79$, adolescents $n = 42$). Fig. 3 gives an overview of the results.

There was a significant main effect of the congruency factor, $F(1,119) = 23.29$, $p < .0001$, $\eta_p^2 = .16$, but as Fig. 3 suggests, there was a trend towards a marginal interaction with age, $F(1,119) = 3.87$, $p = .05$, $\eta_p^2 = .03$. The main effect of age was also significant, $F(1,119) = 6.51$, $p = .01$, $\eta_p^2 = .05$. Follow-up Newman-Keuls contrast tests indicated that the group of adolescents was significantly less confident about their erroneous response on the incongruent problems than about their correct response on the congruent problems (i.e., a 14% confidence drop, $p < .001$). However, this critical confidence decrease was less pronounced in the group of younger children (i.e., 6% decrease, $p = .11$). In sum, the findings clearly indicate that adolescents have some minimal awareness of the inappropriate nature of their attraction errors. However, this attraction error sensitivity is not yet reliable observed in younger elementary school children.

For completeness, we also calculated average confidence ratings for correctly solved incongruent problems and subjected these to a 2 (age, between-subjects) x 2 (congruency, within-subjects) mixed model ANOVA. The data for the correct incongruent problems are also presented in Fig. 3. To avoid confusion, note that a total of 92 individuals failed to solve any of the incongruent problems correctly and could not be included in the analysis (total included $n = 64$; children $n = 28$, adolescents $n = 36$). Clearly, given the lower number of correct answers (especially in the youngest age group), these results should be interpreted with some caution. As Fig. 3 indicates, although the effect was less pronounced than for erroneous responses, confidence tended to be overall lower for correctly solved incongruent problems than for correctly solved congruent problems. Results indeed showed that there was a main effect of congruency, $F(1,62) = 21.34$, $p < .0001$, $\eta_p^2 = .26$, whereas the main effect of age, $F(1,62) = 1.67$, $p = .20$, and the

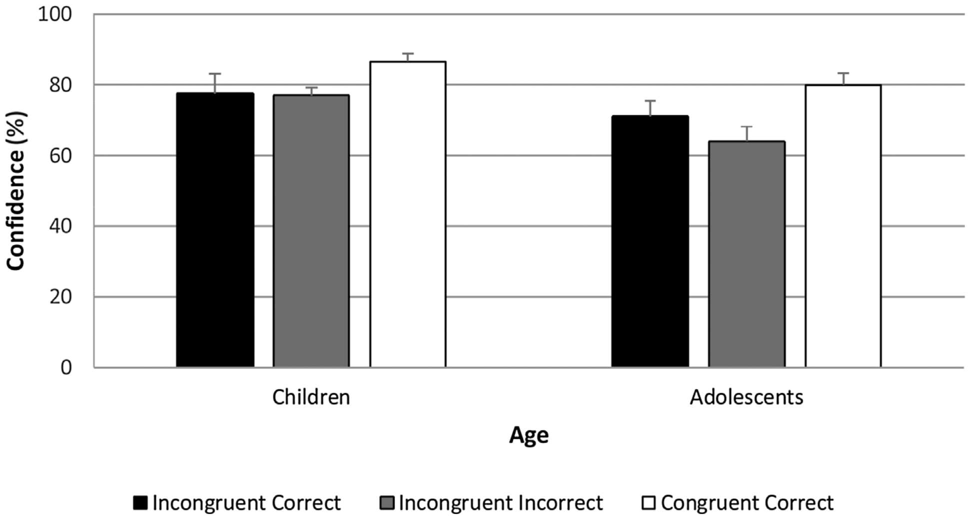

Fig. 3. Average response confidence (%) as a function of response accuracy in the two age groups. Four-point confidence ratings were rescaled as percentage scores. Error bars are standard errors.

congruency and age interaction, $F(1,62) < 1$, were not significant. Hence, for both age groups it was the case that even when the heuristic was correctly blocked, the initial presence of conflict between the cued heuristic and correct response continued to affect one's final response confidence.

2.3. *Individual differences and confidence correlations*

The above analyses indicate that the "average" adolescent detects attraction errors whereas this effect is less clear for the "average" elementary school child. The present study was designed to examine error detection differences at this group level. Looking at the average performance in the group gives us the strongest and most reliable test of the detection question. However, the findings do not imply that all children fail at detecting and all adolescents succeed at it. That is, there might be individual differences in detection efficiency within each age group. Error detection studies in the reasoning field have indicated that such individual differences might be related to performance accuracy (i.e., a more pronounced error detection effect is associated with a lower error rate, e.g., De Neys & Feremans, 2013; Frey, Johnson, & De Neys, 2017; Mevel et al., 2014 Pennycook et al., 2014; Pennycook et al., 2015). To explore this we calculated the correlation between the size of the confidence contrast or *detection effect* (i.e., the % confidence decrease when contrasting erroneously solved incongruent problems and correctly solved congruent problems) and the accuracy on the incongruent problems. The correlation reached overall $r = -.31$, $n = 121$, $p = .0004$, and was present both for children, $r = -.26$, $n = 79$, $p = .020$, and adolescents, $r = -.31$, $n = 42$, $p = .046$. Hence, across age, the individuals with the lowest error rates also tend to show stronger attraction error sensitivity as measured by their confidence ratings. To illustrate this point we have plotted the size of the confidence contrast or *detection effect* for the group of highest and lowest scoring individuals in each age group (high accuracy = at least 50% accuracy, low accuracy = less than 50% accuracy). Note that given the low accuracy rates and differential accuracies these groups differ substantially in size and are often small. Nevertheless, we believe they are helpful to illustrate the obvious but non-trivial point that there can be within-age individual differences. Fig. 4 shows the results. As the figure indicates, it is evident at both age levels that the high accuracy groups shows a more pronounced effect (i.e., confidence decrease) than the low accuracy groups. The effect for the low group also tends to be stronger in the group of adolescents than in the group of children. The key point here is that the children in the high accuracy group tend to show a detection effect that is quite comparable in nominal size to the highly accurate older adolescent group. Again, given the overall low accuracy among children it will be clear that the highly accurate children are a small and select subgroup (i.e., $n = 6$, or less than 10% of the group of children). Hence, some caution is needed when interpreting this result but it underscores the general point that attraction error sensitivity is not completely absent in elementary school.

For completeness, we also correlated the accuracy on the incongruent problems with the confidence contrast for correctly solved incongruent trials (i.e., the % confidence decrease when contrasting correctly solved incongruent problems and correctly solved congruent problems). This correlation was also significant but positive, $r = .41$, $n = 64$, $p = .0008$ (children, $r = .42$, $n = 28$, $p = .025$; adolescents, $r = .41$, $n = 36$, $p = .013$). Hence, the fewer errors one commits, the less one will doubt the correctness of correctly solved incongruent problems. In other words, the individuals with the highest accuracy also tend to be more certain that their answers are factually correct.

3. DISCUSSION

It is well established that children and adolescents frequently make grammatical attraction errors. The present findings establish

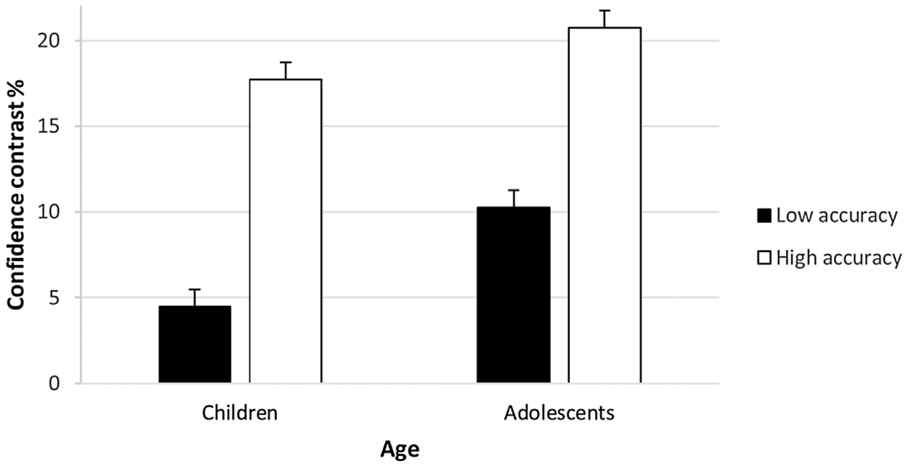

Fig. 4. Confidence contrast (i.e., Incongruent Incorrect confidence − Congruent Correct confidence) for erroneously solved conflict problems in the two age groups as a function of accuracy level. A higher value reflects a more pronounced confidence decrease when solving conflict problems. Error bars are standard errors.

that in those cases where adolescents fail to adhere to the proper grammatical rules and commit attraction errors, they show sensitivity to their errors. Although they might fail to provide a correct answer and succumb to the *"use plural inflection after plurality marker −s"* heuristic, their decreased response confidence indicates that they at least detect that their response is not fully warranted. At the same time the findings also pointed to the development of this error sensitivity efficiency. Our youngest test group of preadolescent elementary school children did not show a reliable error detection effect at the group level yet.

We noted that previous work has attributed attraction errors to a failure to inhibit the automated *"use plural inflection after plurality marker −s"* heuristic in linguistic contexts where it is inappropriate (Lanoë et al., 2016). The present findings allow us to specify the precise nature of the postulated inhibition failure in our two age groups. To recap, the critical question is whether participants predominantly fail to inhibit because they fail to notice that the heuristic is inappropriate (i.e., an error monitoring or detection failure) or because they fail to complete the inhibitory process per se. Hence, the observed less pronounced error sensitivity for younger children suggests that their attraction errors need to be primarily attributed to a monitoring failure. However, the observed error sensitivity in our adolescent group lends credit to the hypothesis that they err because they do not have sufficient resources to successfully complete the inhibition process. In other words, the present findings tentatively suggest that there might be a developmental shift in the precise locus of attraction errors. Both children and adolescents frequently make attraction errors but they tend to err for different reasons.

At the same time our individual difference analysis also indicates that it is important to keep in mind that there is some individual variance in attraction error detection performance. Although our sample of elementary school children failed to show attraction error sensitivity on average, we observed a significant effect for a selective subgroup of best performing children. The individual difference analysis needs to be interpreted with some caution but it helps to remind us that although children might typically struggle to detect attraction errors, successful attraction error sensitivity detection is not completely absent in this age range either.

We believe that it can be interesting to link the present work on attraction error detection to research on bias detection during logical and probabilistic thinking in the reasoning and decision-making field. Classic studies on reasoning and decision-making have long established that people's inferences are often biased by automated heuristics based on prior beliefs and stereotypical intuitions (e.g., Evans, 2010; Kahneman & Tversky, 1973). Recent studies on bias or error monitoring during reasoning have shown that adult reasoners often detect the biased nature of their intuitive logical and probabilistic judgments (e.g., Bonner & Newell, 2010; De Neys, 2012; De Neys & Bonnefon, 2013; De Neys, Rossi, & Houdé, 2013; Mevel et al., 2015; Morsanyi & Handley, 2008; Pennycook & Thompson, 2012; Pennycook et al., 2015; Stupple & Ball, 2008; Thompson & Johnson, 2014; Villejoubert, 2009; but see also Pennycook, Fugelsang, & Koehler, 2012). However, in line with the present findings, developmental studies have indicated that the bias detection during logical and probabilistic reasoning develops with age and is typically not observed before the onset of adolescence (e.g., De Neys et al., 2011 ; De Neys & Feremans, 2013). This developmental similarity in error detection across different domains lends some credence to the idea that adolescence is a key stage in the development of general cognitive monitoring and control abilities (e.g., Davies et al., 2004; Fitzgerald et al., 2010; Santesso & Segalowitz, 2008).

To be clear, a less developed error monitoring function does not imply that children will never detect errors (Lubin, Simon, Houdé, & De Neys, 2015). Indeed, basic error monitoring studies have shown that even three-year-olds can detect errors in simple tasks that do not cue a strong heuristic response (Lyons & Ghetti, 2011). Likewise, De Neys et al. (2014) showed that preschoolers can show sensitivity to errors on Piaget's classic number conservation tasks (see also Simon et al., 2015). Clearly, one needs to bear in mind that the specific demands of the monitoring process can differ across tasks which might result in different developmental patterns. Nevertheless, the present findings suggest that in the specific case of grammatical verb inflection, monitoring for attraction errors is presumably too demanding for most preadolescent children.

We hope that with the present study we managed to illustrate the importance of testing the attraction error detection efficiency. Nevertheless, when considering the implications of the findings it is important to bear in mind that the study is but the first to start addressing this issue. In this respect we want to stress a number of caveats and directions for future research. First, it will be important to validate and generalize the present findings in future studies. These future studies might for example explore different error detection measures (e.g., reaction times or fMRI, see further) to validate the present behavioral data. At the behavioral level, additional latency measures might be useful. Reasoning studies have indicated that the doubt associated with error detection typically also results in increased processing times in addition to a lowered response confidence (e.g., Frey et al., 2017; Mevel et al., 2015; Pennycook et al., 2014; Stupple et al., 2013). One advantage of latency measures over confidence ratings is that they allow online tracking of the error detection. Since confidence ratings are collected after the response is given it is not clear whether the error detection occurs while the response is generated or whether it results from post-response reassessment. Second, our study was conducted in France and focused on attraction errors in the typical French "Singular subject pronoun + Plural pronoun + Verb" case. Although previous research has not pointed to systematic differences in attraction errors in English and French (Bock, 1995; Bock & Cutting, 1992; Bock & Eberhard, 1993; Bock & Miller, 1991; Nunes et al., 1997c; Vigliocco et al., 1996 Vigliocco, Butterworth & Semenza, 1996; Chanquoy & Negro, 1996; Fayol et al., 1994; Largy, Dédéyan, & Hupet, 2004), it will be important to replicate the present study in different countries and with different languages. Third, one might try to improve the ecological validity of the test design. Note that in our forced-choice task design participants are always presented with both the correct and incorrect answer. This might facilitate monitoring and error detection. This can be further enhanced by the fact that participants know that they are participating in a scientific study in which their performance is being monitored. Hence, as always, some caution is needed when generalizing the current lab-based results to a more naturalistic setting. Finally, we noted that our developmental hypothesis was inspired by neuropsychological work that pointed to the late maturation of the Anterior Cingulate Cortex (ACC), the critical brain structure that is supposed to be mediating conflict and error detection (e.g., Davies, Segalowitz, & Gavin, 2004; De Neys, Vartanian, & Goel, 2008; Fitzgerald et al., 2010; Santesso & Segalowitz, 2008; Simon et al., 2015). Given the present results it would be interesting to complement our behavioral findings with neuroimaging work and see whether attraction errors in different age groups are accompanied by a differential ACC activation pattern.

In closing, we would like to highlight a potential implication of the observed attraction error sensitivity for ongoing educational debates in the popular media. Over the last years numerous reports raised worries about teenagers' declining writing and grammar skills (e.g., Aalai, 2014; Alston, 2015; Houston Chronicle, 2012). In the case of grammatical attraction errors, the evidence for adolescents' error sensitivity implies that they are savvier about verb inflection rules than the massive attraction errors might seem to suggest. Although adolescents might not always make correct decisions, their error sensitivity indicates that they do have some minimal insight into the proper verb inflection rules. In general, this should remind us that when evaluating cognitive performance, we need not only focus on outcome measures (e.g., does one write correct or not?) but also to the cognitive processing that resulted in that outcome. The present study underscores that grammatical errors do not necessarily point to a lack of grammatical knowledge. Hence, the good news implied here is that when adolescents commit attraction errors they are probably less grammatically oblivious than some worried parents or teachers might fear.

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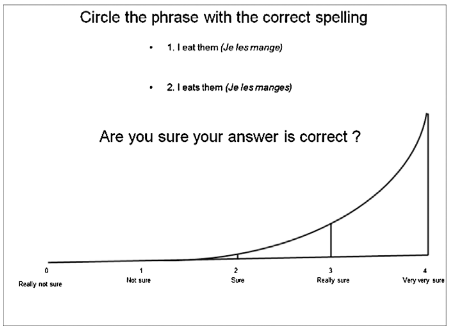
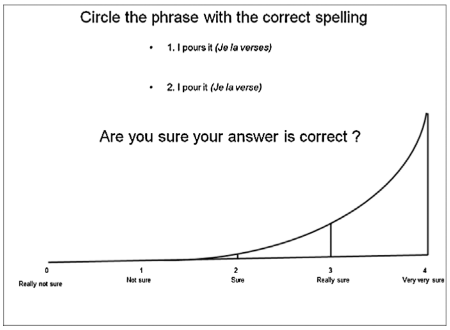
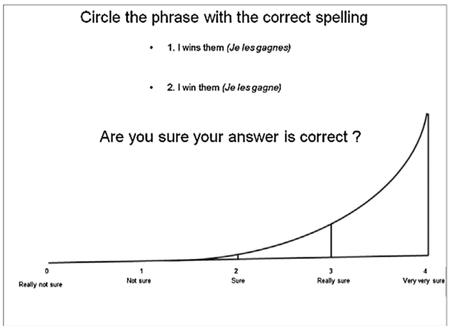
Appendix A. Overview material used for grammatical problems. We present the English translation of the items. For completeness, the original French sentences are presented between parentheses



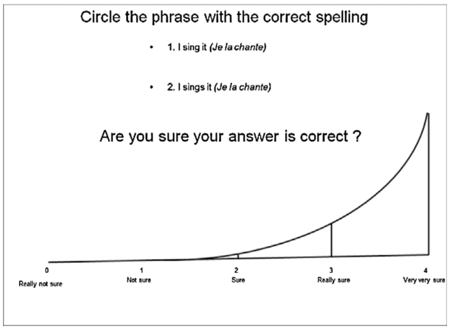
Problem 1:



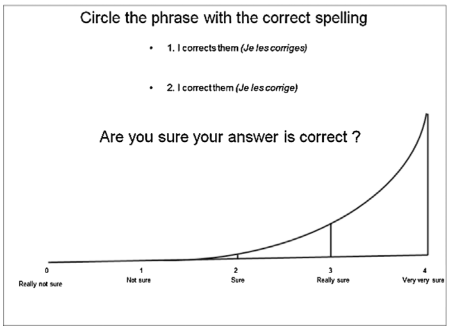
Problem 2:



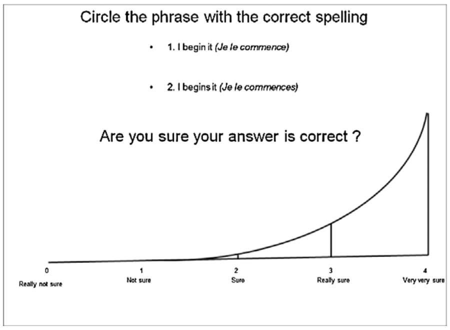
Problem 3:



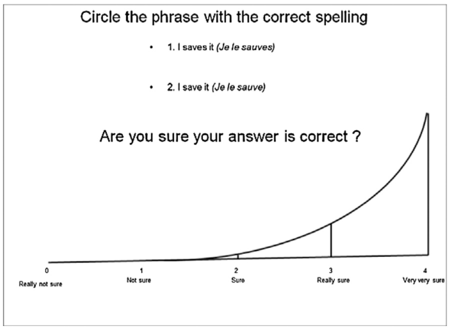
Problem 4:



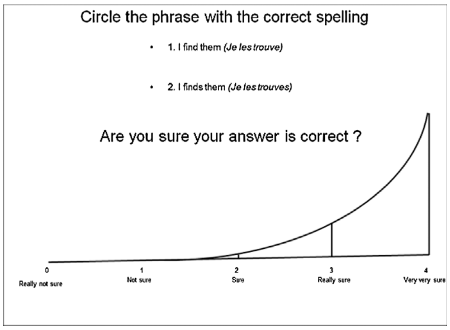
Problem 5:



Problem 6:



Problem 7:



Problem 8:

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