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Abstract

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On the locus of grammatical context effects on word recognition

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ABSTRACT
While grammatical context effects have been largely documented, their exact nature remains unclear. To determine the locus of these effects, we explored the priming in very strong grammatical contexts, that is, the priming of verbs by immediately preceding French pronominal subjects. In French, the first and second person plural pronouns are always associated with the same verbal inflections, creating very strong grammatical contexts. Participants made lexical decisions on targets (verb vs. pseudoverb) which were presented in three contexts: pronoun-congruent (nous grimpons, we climb), pronoun-incongruent (vous grimpons, you climb) or pseudoword control (zous grimpons, zous climb). Two experiments were conducted: one in the auditory modality and one in the visual modality. Grammatical context effects in the auditory modality did not vary as a function of the ISI, and no grammatical context effect was observed in the visual modality when the context was presented subliminally. These findings suggest that grammatical context effects operate at a post-lexical locus.

Le locus des effets du contexte grammatical dans la reconnaissance des mots

RÉSUMÉ
Tandis que des effets du contexte grammatical ont été largement décrits, leur nature exacte reste encore peu claire. Afin d’établir le locus de ces effets, nous avons exploré...

1. INTRODUCTION

The language input that we perceive is typically composed of strings of words. Consequently, any given word is generally preceded by other words which create its sentential context. It has consistently been observed that words in context are recognized more rapidly and easily than isolated words due to this predictive context. Autonomous and interactive theories propose alternative accounts for the precise nature of context effects (see reviews, Forster, 1979; Frauenfelder & Tyler, 1987; Tanenhaus & Lucas, 1987). According to the autonomous hypothesis, called also the modularity hypothesis, the language system is composed of a set of distinct modules (e.g., semantic, syntactic, lexical, and phonological) that are functionally autonomous. In language comprehension, the information flow between modules is constrained so that higher level information (e.g., semantic and syntactic) cannot influence lower level processes (e.g., lexical and phonological) directly and immediately. Here, any observed semantic or syntactic effects on word recognition are considered to be post-lexical, i.e., due to processes that occur after word recognition is completed. In contrast, in interactive models, semantic or syntactic levels exchange information with the lexical processing bidirectionally (Marslen-Wilson & Welsh, 1978, Morton, 1969). Hence, semantic or syntactic context constrains the early stages of word recognition and increases the levels of activation of predicted words, possible even before they have been entirely received.

In this paper, we aim to study the locus of grammatical context effects, and more specifically to determine how and when a morphosyntactic context marking the agreement between a pronoun and a verb influences the recognition of this inflected verb. While less extensively studied than semantic context effects, grammatical context effects have, nonetheless,
attracted some attention. The grammatical effects have generally been attributed in an autonomous perspective to the post-lexical integration of a critical word with the preceding words. In contrast, in the interactive perspective they are seen to be due to the automatic activation of the target word and its inflection by the preceding context, thus operating at a lexical locus. Here, we examined the influence of grammatical context afforded by a pronoun on the following inflected verb. We created extremely predictive grammatical contexts based on the agreement of inflectional morphemes, that were much stronger than those, for example, used for predicting the grammatical category of a word. To explore this question, we compared the presentation conditions of primes and targets in ways that have been assumed to distinguish between the two theoretical explanations proposed for context effects.

Two methodological approaches have been employed to probe the locus of grammatical context effects in word recognition. One involves manipulating the temporal interval separating the context from the next word. This approach is based on the traditional distinction between controlled and automatic processes, as proposed by Posner and Snyder (1975) and Schneider and Shiffrin (1977). Whereas automatic activation triggered by the context is considered to occur quickly at the lexical level, post-lexical integration is assumed to have the properties of controlled processes, i.e., slow effects that increase with longer time intervals separating prime and target. Lukatela, Moraca, Stojnov, Savic, Katz and Turvey (1982) investigated whether the size of grammatical context effects for visually-presented Serbo-Croatian pronouns and verbs varied as a function of the time interval between the onset of pronoun primes and that of verb targets (called stimulus onset asynchrony, SOA\(^1\)). These authors showed that verbs were recognized faster in the congruent context than in the incongruent context, and this congruency effect was greater for a longer SOA (800 ms) than for a shorter one (300 ms). Since controlled processes are assumed to take time and emerge more at longer SOAs, the authors concluded in favor of a post-lexical checking locus of grammatical context effects.

The second related methodological approach for determining the locus of grammatical context effects is also based on the distinction between controlled and automatic processes. It further reduces the processing time of the prime and involves masking this context to avoid

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\(^1\)The Stimulus Onset Asynchrony (SOA) refers to the temporal interval between the onset of the prime and that of the target. This parameter is generally used in defining visual priming.
its conscious perception. Whereas automatic activation triggered by the context is considered to occur without conscious perception of the context, post-lexical processes require a conscious access to the context. Using this approach, Lukatela, Carello and Turvey (1990) explored the influence of case-marked adjectives on the recognition of Serbo-Croatian nouns. Although under unmasked conditions a grammatical congruency effect was obtained, this effect was not observed when the adjectives were masked. Again, the finding of this study supports a post-lexical view of grammatical context effects. Overall, these studies, which involved either manipulating the temporal interval separating the grammatical context from the next word or visually masking the grammatical context, favor a post-lexical checking locus.

In this study, we seek to identify the locus of grammatical context effects on inflected words by using each of the two methodological approaches employed by these previous studies. In order to test the hypotheses that grammatical context effects are attributable to automatic lexical activation, we examined the locus of grammatical context effects in conditions assumed most likely to produce automatic lexical activation of the target by the context. Note that the previous studies (Lukatela, Moraca, Stojnov, Savic, Katz, & Turvey, 1982; Lukatela, Carello, & Turvey, 1990; Gurjanov, Lukatela, Lukatela, Savić, & Turvey, 1985; Gurjanov, Lukatela, Moskovljević, Savić, & Turvey, 1985) which supported a post-lexical locus of grammatical context effects did not make methodological choice that most favored the emergence of an early locus of grammatical context effects. For example, the choice by Lukatela and his colleagues of the strength of grammatical constraints imposed by the context could have prevented them from observing automatic spreading activation in their previous studies. In particular, these studies generally used open-class words (for example, adjectives) rather than closed-class words such as a grammatical context. The former are known to produce weaker grammatical context effects that the latter (Colé & Segui, 1994). In addition, in the studies that did use grammatical contexts involving single closed-class words as primes, these primes were not associated exclusively with a single verbal inflection in Serbo-Croatian (Lukatela et al., 1982). More specifically, Lukatela and colleagues (1982) explored the influence of pronouns on verb recognition in cases where the same personal pronoun could be associated with several verbal inflections as a function of tense of the verb. We expected that the strength of automatic spreading activation induced by the grammatical context would depend directly on the strength of the grammatical constraints imposed by the context (as
predicted by probabilistic constraints models, MacDonald, Pearlmutter, & Seidenberg, 1994; Seidenberg & MacDonald, 1999). Consequently, the failure to observe automatic spreading activation in these studies may in part have been the result of the weak grammatical constraining contexts.

Our study aimed at investigating the locus of grammatical context effects in the case of a strongly constraining context between a contextual closed-class word and the expected morpheme. French offers an interesting case of strong context between the context and the expected morpheme within the French pronominal subject-verb agreement relation. More precisely, the verbal inflections which signal the first and second person plural, respectively -ons and -ez, are identical in all tenses (with the exception of the past subjunctive, a tense which is almost never used) and are not associated with other features. Consequently, the first and second person plural pronouns are always associated with the same verbal inflections (apart from a very few irregular verbs). Since the grammatical context that we used was strongly constraining and consisted of a closed-class word, it offered conditions that were conducive for observing a potential automatic spreading activation triggered by the context.

Finally, most studies of grammatical context effects, as described above, were conducted in the visual modality. However, grammatical context effects attributed to automatic spreading activation have generally been observed in the auditory modality (Dahan, Swingley, Tanenhaus, & Magnuson 2000; Friederici & Jacobsen, 1999; Spinelli & Alario, 2002). Indeed, the studies that claimed to reveal automatic activation in gender agreement generated by the context presented their stimuli in the auditory modality (Dahan, Swingley, Tanenhaus, & Magnuson, 2000; Spinelli & Alario, 2002). To examine the effect of modality, we studied grammatical context effects in the auditory and visual modalities using the two different methodological approaches to priming typically found in each modality.

We first examined grammatical priming in the auditory modality, which is assumed to be better suited for observing automatic spreading activation triggered by the grammatical context. To do so, we adopted the first approach described above and manipulated the temporal interval between the context and the upcoming word. If the observed grammatical context effects decreased or disappeared with the long interstimulus interval between the offset of pronoun primes and the onset of verb targets (ISI²) as compared to the shorter ISI, we could argue for an automatic spreading

²The interstimulus interval (ISI) refers to the temporal interval between the offset of prime and the onset of the target. This parameter is generally used in defining auditory priming.
lexical activation account (for similar interpretations in auditory modality, see Luce, Goldinger, Auer, & Vitevitch, 2000 and Radeau, Morais, & Segui, 1995).

Three types of prime-target pairs were used to test for grammatical context effects: pronoun-congruent (nous grimpons, “we climb”) in which the pronoun prime matched the target’s verbal inflection according to French agreement rules, pronoun-incongruent (vous grimpons, “you climb”) in which the pronoun prime did not match the verbal inflection of targets, and the pseudoword control3 (zous grimpons, “zous climb”) in which a pseudoword resembled the pronoun prime. Faster lexical decision latencies in the pronoun-congruent context compared to the pronoun-incongruent context constitute a congruency effect. Facilitatory and inhibitory priming effects by the grammatical context can be identified by comparing pronoun-congruent or pronoun-incongruent context with the control context. By including these three contexts, we hoped to establish the nature of the grammatical priming effects. Although inhibitory priming effects have usually been interpreted as reflecting processes acting at a post-lexical locus, facilitatory priming effects have been attributed to automatic lexical activation of the target (e.g., Bates, Devescovi, Hernandez, & Pizzamiglio, 1996; Friederici & Jacobsen, 1999).

Secondly, we examined grammatical context effects in the visual modality using two different presentation conditions: a control condition with unmasked presentations of the prime (350 ms) and a subliminal priming condition (53 ms) (see Segui & Grainger, 1990 and Grainger, Diependaele, Spinelli, Ferrand, & Farioli, 2003, for similar presentation times of visual primes). The first condition allowed us to determine whether the strongly constraining context between a contextual closed-class word and the expected morpheme is sufficient to produce grammatical context effects. The second condition adopted the second methodological approach described above and used subliminal presentations of the prime. This condition should allow us to determine whether these effects are due to automatic spreading activation. Importantly, the subliminal condition prevents the participant from engaging in conscious processing of the prime, thus providing the most robust condition to test the locus of grammatical context effects. Indeed, even if the manipulation of the temporal interval between the context and the upcoming word is a useful

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3Since all French pronouns provide grammatical cues, we used a pseudoword in the control context. Here this pseudoword cannot preactivate or predict any verbal inflection, but shares its form features with pronouns to force participants to process the primes.
methodological approach, it is somewhat limited by the fact that the prime is perceived consciously.

In sum, we examined the effect of grammatically congruent, incongruent and pseudoword control primes on a subsequent lexical decision on verb targets in an auditory grammatical priming experiment. We used either a short or a long ISI between the prime and the target (Experiments 1a and 1b). We also conducted a visual grammatical priming experiment, either with a presentation duration allowing the recognition of the visual prime (Experiment 2a) or with a subliminal presentation of the visual prime (Experiment 2b).

2. EXPERIMENT 1: AUDITORY GRAMMATICAL PRIMING

2.1. Method

2.1.1. Participants

Forty-eight native French-speaking students (forty-two female, six male) from the University of Geneva, aged 19-36 years old, took part in Experiment 1a (short ISI). Forty-two native French-speaking students (thirty-six female, six male) participated in Experiment 1b (long ISI). None of the participants had neurological or hearing impairments. They participated for course credits after having given their written informed consent. The experiment was approved by the Psychology Research Ethics Committee of the University of Geneva.

2.1.2. Stimuli

The targets were composed of 60 French verbs and 60 pseudowords which ended with the verbal inflections –ons or –ez. Each verb ended either in the first person plural marked by the verbal inflection –ons or in the second person plural marked by the verbal inflection –ez. Pseudoword targets were constructed by replacing the entire first syllable of the word targets but respecting French phonotactic rules. All targets contained five phonemes. Pseudowords targets were used for the requirement of the lexical decision task. All word targets are listed in the Appendix. As primes, we chose the two corresponding personal pronouns nous and vous (first and second person plural respectively) and a pseudopronoun zous. The first and second person plural pronouns4 (nous and vous) in French are associated with the

4In French, the first and second person plural pronouns (nous and vous) can be used together as subject and object pronouns. Hence, for transitive verbs, a sentence such as nous vous défions (“we dare you”) in which the second person plural object pronoun vous immediately precedes the first person plural subject pronoun is acceptable. However, prime-target pairs with a pronominal subject prime immediately followed by a verbal form where the verbal inflection does not agree with the pronoun are clearly grammatically incorrect.
verbal inflections –ons and –ez respectively, whereas the non-predictive prime [zu] is not associated with any inflection. All stimuli were produced several times by a female speaker of French and were recorded at 44100 Hz. The primes [nu], [vu] and [zu] were resynthesized in such a way that their duration (always 342 ms) and their fundamental frequencies matched.

2.1.3. Design

Three experimental lists of 60 prime-target pairs were created. Three types of prime-target pairs were used (see Table 1). In the pronoun-congruent context, the pronoun prime (nous or vous) matched the target’s verbal inflection according to French agreement rules. In the pronoun-incongruent context, the pronoun prime did not match the verbal inflection of targets. In the control context, the pseudopronoun zous was followed by either first or second person plural targets. Thus, each experimental list contained twenty prime-target pairs from each context. The use of three experimental lists allowed us to introduce each target into all three contexts across participants.

Table 1. Examples of stimuli in the three contexts

<table>
<thead>
<tr>
<th>PRIMES</th>
<th>Congruent-pronoun</th>
<th>Incongruent-pronoun</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Targets</td>
<td>Words</td>
<td>Words</td>
<td>Words</td>
</tr>
<tr>
<td></td>
<td>nous grimpons</td>
<td>vous grimpons</td>
<td>zous grimpons</td>
</tr>
<tr>
<td></td>
<td>(we climb)</td>
<td>(you climb)</td>
<td>(zous climb)</td>
</tr>
<tr>
<td></td>
<td>vous valsez</td>
<td>nous valsez</td>
<td>zous valsez</td>
</tr>
<tr>
<td></td>
<td>(you waltz)</td>
<td>(we waltz)</td>
<td>(zous waltz)</td>
</tr>
</tbody>
</table>

2.1.4. Experimental procedure

Each trial started with a fixation point in the middle of the screen, which was presented 500 ms before the auditory prime. The auditory prime was followed by the auditory target after a silence of 50 ms for Experiment 1a, or of 500 ms for Experiment 1b. The auditory stimuli were presented binaurally at a comfortable sound level via headphones. An inter-trial interval of 2,000 ms elapsed between the participant’s response and the beginning of the next trial. Participants were instructed to indicate, as quickly and accurately as possible, whether the target was a French word or not by pushing one of two buttons on a response box. The response buttons were distributed to the participants according to their handedness and counterbalanced across all participants. Response times (RTs) were measured from the onset of the target. Participants first received 12 practice prime-target pairs, and then a block of 120 prime-target pairs presented randomly in an experiment which lasted 10 minutes.
Since grammatical context effects attributed to automatic spreading lexical activation have tended to emerge more in the auditory than the visual modality (Dahan, Swingley, Tanenhaus, & Magnuson, 2000; Friederici & Jacobsen, 1999; Spinelli & Alario, 2002), we expected to observe grammatical context effects that were stronger at the shorter ISI (50 ms) than at the longer ISI (500 ms).

2.2. Results

2.2.1. Experiment 1a: Auditory grammatical priming with a short ISI

Five items giving rise to more than 30% of errors were excluded from the analyses (for similar approach, e.g., Havelka, Bowers, & Jankovic, 2006; Kouider & Dupoux, 2005). For each participant and for each context, both RTs longer than 1800 ms and those greater than 2.5 standard deviations above and below the participant’s overall response were excluded from the analyses. As the RTs varied as a function of the physical duration of the targets, we selected a cut-off criterion for excluding RTs (longer than 1800 ms) that was based on the distribution of RTs (i.e., 5 standard deviations above the grand mean, see, Baayen, McQueen, Dijkstra, & Schreuder, 2003). Mean RTs and error data\(^5\) per context are shown in Table 2. We conducted ANOVAs on the RTs and the error rates by participants (F\(_1\)) and by items (F\(_2\)) with Context (pronoun-congruent, pronoun-incongruent, control) as

\[\begin{array}{|c|c|c|}
\hline
\text{Context} & \text{Response times (ms)} & \text{Error rates (%)} \\
\hline
\hline
\text{Long ISI} & \text{Word Targets} & \\
\text{Congruent-pronoun} & 951 & 2 \\
\text{Control} & 989 & 5.1 \\
\text{Incongruent-pronoun} & 1026 & 6.8 \\
\hline
\text{Short ISI} & \text{Word Targets} & \\
\text{Congruent-pronoun} & 985 & 1.9 \\
\text{Control} & 1005 & 2.5 \\
\text{Incongruent-pronoun} & 1045 & 4.8 \\
\hline
\end{array}\]

\(^5\)The error rates near or superior to 5% in all experiments could be due to a low frequency of verbal forms (respectively 0.5 from a corpus of films and 0.2 from a written Frantext corpus). The word frequency assessed in number of occurrence per million was extracted from Lexique database (New, Pallier, Ferrand, & Matos, 2001).
factors. The response times analysis on the word targets showed an overall effect of Context (F1(2,94) = 32.09, p < .001, F2(2,108) = 38.28, p < .001). It showed an effect of congruency with faster RTs in the pronoun-congruent context than in the pronoun-incongruent context (F1(1,47) = 61.7, p < .001, F2(1,54) = 79.84, p < .001). Moreover, it also showed an effect of facilitation, faster RTs in the pronoun-congruent context than in the control context (F1(1,47) = 19.55, p < .001, F2(1,54) = 21.43, p < .001) and an effect of inhibition, slower in the pronoun-incongruent context than in the control context (F1(1,47) = 14.2, p < .001, F2(1,54) = 22.09, p < .001).

We observed an effect of Context (F1(2,94) = 7.46, p < .001, F2(2,108) = 11.47, p < .001) for error rates. Participants performed better in the pronoun-congruent context than in the control context (F1(1,47) = 8.58, p < .05, F2(1,54) = 10.76, p < .05) and in the pronoun-incongruent context (F1(1,47) = 19, p < .001, F2(1,54) = 16.43, p < .001). The by-item analysis showed that the performance of participants was worse in the pronoun-incongruent context than in the control context (F2(1,54) = 3.75, p = .05) but this effect was not observed by participants analysis (F1(1,47) = 1.2, p > .2).

2.2.2. Experiment 1b: Auditory grammatical priming with a longer ISI

As with Experiment 1a, the same five items giving rise to more than 30% of errors were excluded from the analyses. Mean RTs and error data per context are shown in Table 2. We conducted ANOVAs on the RTs and the error rates by participants (F1) and by items (F2) with Context as the main independent variable. The analysis of response times revealed a Context effect (F1(2,82) = 18.51, p < .001, F2(2,108) = 22.28, p < .001). RTs in the pronoun-incongruent context were longer than in the control context (F1(1,41) = 15.44, p < .001, F2(1,54) = 21.42, p < .001) and in the pronoun-congruent context (F1(1,41) = 38.48, p < .001, F2(1,54) = 48.3, p < .001). The participants analysis showed that response times in the pronoun-congruent context tended to be shorter than in the control context (F1(1,41) = 3.61, p = .06). No significant effect between the pronoun-congruent context and the control context was found for the items analysis (F2(1,54) = 2.58, p = .11).

In the analysis of error rates, we also found a main effect of Context (F1(2,82) = 4.99, p < .05, F2(2,108) = 5.43, p < .05). Participants performed better in the pronoun-congruent context than in the pronoun-incongruent context (F1(1,41) = 7.46, p < .05, F2(1,54) = 8.93, p < .05). No
significant difference between the pronoun-congruent context and the control context was obtained ($F_1(1,41) = 0.56, p > .2, F_2(1,54) = 0.50, p > .2$). Participants made more errors in the pronoun-incongruent context than in the control context ($F_1(1,41) = 5.22, p < .05, F_2(1,54) = 4.96, p < .05$).

2.3. Discussion: Experiments 1a and 1b

Whereas facilitatory and inhibitory context effects were clearly observed, respectively in pronoun-incongruent and pronoun-congruent contexts with respect to the control context in Experiment 1a, an inhibitory context effect was found in Experiment 1b but the facilitatory context effect only approached the level of significance. Importantly, the results showed the same pattern descriptively in both experiments, such that RTs were shorter in the pronoun-congruent context relative to the pronoun-incongruent and control contexts and were longer in the pronoun-incongruent context relative to the control context. To examine whether the size of grammatical context effects decreased with a longer ISI, we conducted supplementary analyses. When the data from Experiments 1a and 1b were combined in a statistical analysis, we observed no Context × ISI interaction for RTs ($F_1(2,176) = 1.08, p > .2, F_2(2,216) = 1.64, p > .2$) or for error rates ($F_1(2,176) = 1.24, p > .2, F_2(2,216) = 1.75, p = .18$). This suggests that the grammatical context effects that we found in Experiment 1a with a short ISI did not change with the increase of ISI in Experiment 1b. Additionally, supplementary analyses based on the comparisons between each context (pronoun-congruent context vs. control context, pronoun-congruent context vs. pronoun-incongruent context, pronoun-incongruent context vs. control context) showed no effect of ISI ($p > .2$). Given that the absence of differences in the size of the context effects obtained at the two ISIs, it seems difficult to decide between accounts based on automatic spreading lexical activation or post-lexical locus. In general, larger context effects at longer ISIs are interpreted as showing the involvement of post-lexical process, as in the study of Lukatela et al. (1982). But this pattern of results was not observed when we manipulated the ISI. Note that, according to the automatic account, the lexical activation due to the primes should decrease or disappear at longer ISIs (Radeau, Morais, & Segui, 1995 and Luce, Goldinger, Auer, & Vitevitch, 2000). Similarly to Katz, Boyce, Goldstein and Lukatela (1987) who manipulated the duration of the ISI in an auditory grammatical priming experiment, the size of grammatical context effects did not vary as a function of ISI in our experiments. One way to explain this finding could be that the consciously
perceived context triggered expectations of one set of multiple verbal forms sharing the same morphosyntactic features in accordance with the French subject-verb grammatical rules but having different stems. Indeed, even if the grammatical context produced by a pronoun is very constraining on the verb’s inflection, the pronoun probably does not induce the expectation of one specific inflected verb. In other words, for example, when the first person plural pronoun is perceived, all inflected verbs marked by the verbal inflection –ons could be expected. Also, the relevant information regarding the verbal inflection arrives late after the processing of the stem, and thus participants have much time to generate such expectations at both ISI (short or long). Then, post-lexical checking can occur based on context-based expectations. According to Deustch and Bentin (1994), when expectations are not met as in incongruent-pronoun context, a second checking analysis between the inflection and the context can be triggered. In line with this assumption, post-hoc statistical analysis of pseudowords showed that participants rejected the pseudowords more quickly when their verbal inflection did not agree with the context compared to when the verbal inflection was either agreed with the context or was preceded by a control context at both ISIs \( (p < .05) \). In sum, contrary to our predictions, the two auditory grammatical priming experiments suggest a post-lexical locus of grammatical context effects.

3. EXPERIMENT 2: VISUAL GRAMMATICAL PRIMING

3.1. Method

3.1.1. Participants

Forty-two native French-speaking students (thirty-six female, six male) from the University of Aix-Marseille participated in Experiment 2a. Thirty-nine other native French-speaking students (thirty-three female, six male) from the University of Geneva, aged 19-30 years old, participated in Experiment 2b. None of the participants had neurological or language impairments. They participated for course credits after having given their written informed consent. The experiment was approved by the Psychology Research Ethics Committee of the University of Geneva.

3.1.2. Stimuli

Targets and primes in this experiment were the orthographical forms of the stimuli presented in Experiment 1. The words and pseudowords targets were made up
of five to nine letters (mean = 6.8 letters). All primes contained four letters. The experimental design of Experiment 2 was similar to that of Experiment 1.

3.1.3. Experimental procedure

The experimental session consisted of one practice block followed by the experimental list, and then a prime visibility test. Each trial of the practice and experimental lists began with the presentation of a forward mask corresponding to ten hash marks in the middle of the screen for 500 ms before the visual prime. The lowercase prime stayed on the screen for 350 ms in Experiment 2a and for 53 ms in Experiment 2b. The choice of a short prime duration of around 50 ms in Experiment 2b was based on previous studies (Diependaele, Sandra, & Grainger, 2005; Grainger, Diependaele, Spinelli, Ferrand, & Farioli, 2003; Kouider & Dupoux, 2001), that suggest that this range of duration is optimal for creating subliminal conditions. The exact prime duration was determined by the refresh rate of monitor (here, 75Hz). In both conditions the prime was then replaced by a backward mask composed of a pseudorandom string of ten uppercase consonants. The backward mask was presented for 13 ms and was followed by the lowercase targets. For each target, a backward mask was constructed so that the mask did not share consonants with the target or the different primes. The same backward mask was used for each target across all contexts. An inter-trial interval of 2000 ms elapsed between the participant’s response and the beginning of the next trial. Participants were instructed to indicate, as quickly and accurately as possible, whether the target was a French word or not by pushing one of two buttons on a response box. The response buttons were assigned to the participants according to their handedness and counterbalanced across all participants. Visual stimuli were presented on a monitor with a 75-Hz refresh rate in white against a black background. Participants first received 12 practice prime-target pairs, and then the list of 120 randomly presented prime-target pairs.

The prime visibility test was based on the experimental procedure of the two presentation conditions. Ten new prime-target pairs for each context were constructed. Rather than making a lexical decision, participants were asked to identify the primes and mention the letters that they thought they had seen. We measured the rate of correct prime identification. Participants perceived all primes correctly in Experiment 2a. Only the participants who did not perceive the prime or/and did not recognize one of letters of the primes were included in the data analyses of Experiment 2b. Three participants were excluded from the data analyses because they recognized correctly more than half of primes in prime visibility test. Following the previous results of Lukatela, Carello and Turvey (1990) and Lukatela et al. (1982), we could expect that a grammatical congruency effect, that is, faster reaction times in the pronoun-congruent context compared to the pronoun-incongruent context would be obtained for the longer prime presentation condition (Experiment 2a), but no such effect in the subliminal priming condition (Experiment 2b). Such an interaction between grammatical congruency and presentation condition would reinforce the claim that the locus of grammatical context effects is post-lexical.
3.2. Results

3.2.1. Experiment 2a: Conscious visual grammatical priming

Six items giving rise to more than 30% of errors were excluded from the analyses. For each participant and for each context, both response times (RTs) longer than 1500 ms (see, Colé & Segui, 1994; Grainger, Diependaele, Spinelli, Ferrand, & Farioli, 2003) and those greater than 2.5 standard deviations above and below the participant’s overall response were excluded from the analyses. We conducted ANOVAs on the RTs and the error rates by participants (F₁) and by items (F₂), with Context (pronoun-congruent, pronoun-incongruent, control) as the main independent variable. Mean RTs and error rates for the three contexts are displayed in Table 3. The analysis of the response times on word targets revealed an effect of Context (F₁(2,82) = 3.01, p < .05, F₂(2,106) = 3.14, p < .05). Response times in the pronoun-congruent context were shorter than those in the pronoun-incongruent context (F₁(1,41) = 6.89, p < .05, F₂(1,53) = 5.37, p < .05). The by-participants analysis showed that response times in the pronoun-incongruent context tended to be longer than those in the control context (F₁(1,41) = 3.01, p = .08). No significant effect between the pronoun-incongruent context and the control context was found for the items analysis (F₂(1,53) = 2.3, p = .13). Additionally, we also observed no significant difference in RTs between the pronoun-congruent context and the control context (F₁(1,41) = 0.31, p > .2, F₂(1,53) = 1.06, p > .2).

As with the RTs analysis, the analysis of error rates showed an effect of Context (F₁(2,82) = 3.78, p < .05, F₂(2,106) = 4.30, p < .05). Participants made more errors in the pronoun-incongruent context than in the control context.

Table 3. Mean response times (in ms) measured from the display of the target and mean error rates (in %) for the three contexts in conscious and subliminal visual grammatical priming (Experiments 2a and 2b)

<table>
<thead>
<tr>
<th>Context</th>
<th>Response times (ms)</th>
<th>Error rates (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Subliminal</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Congruent-pronoun</td>
<td>724</td>
<td>6.9</td>
</tr>
<tr>
<td>Control</td>
<td>729</td>
<td>7.9</td>
</tr>
<tr>
<td>Incongruent-pronoun</td>
<td>746</td>
<td>10.6</td>
</tr>
<tr>
<td><strong>Conscious</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Congruent-pronoun</td>
<td>709</td>
<td>8.8</td>
</tr>
<tr>
<td>Control</td>
<td>709</td>
<td>8.3</td>
</tr>
<tr>
<td>Incongruent-pronoun</td>
<td>710</td>
<td>8.6</td>
</tr>
</tbody>
</table>

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in the pronoun-congruent context \( (F_1(1,41) = 7.86, p < .05, F_2(1,53) = 8.23, p < .05) \). The items analysis also revealed that participants tended to be worse in the pronoun-incongruent context than in the control context \( (F_2(1,53) = 3.43, p = .06) \). No significant effect between the pronoun-incongruent context and the control context was observed in the participants analysis \( (F_1(1,41) = 2.53, p = .12) \). The performance of participants in the pronoun-congruent relative to the control context did not differ \( (F_1(1,41) = 0.89, p > .2, F_2(1,53) = 0.82, p > .2) \).

3.2.2. Experiment 2b: Subliminal visual grammatical priming

For the analysis of response times and of error rates, we found no effect of Context \( (RT, F_1(2,70) = 0.04, p > .2, F_2(2,106) = 0.13, p > .2; \) error rates, \( F_1(2,70) = 0.05, p > .2, F_2(2,106) = 0.04, p > .2) \).

3.3. Discussion: Experiments 2a & 2b

When participants consciously perceived the visually presented prime, they recognized word targets faster in the pronoun-congruent context than in the pronoun-incongruent context. Unlike for the auditory experiments, the visual presentation of conscious primes did not elicit a facilitatory context effect. Hence, the difference between the pronoun-congruent and pronoun-incongruent contexts in Experiment 2a is an incongruency effect. As mentioned by Katz et al. (1987), the specificity of visual presentation relative to the auditory modality is the simultaneous presentation of the stem and its verbal inflection. It seems here that the incongruence between the target and the context inhibits the lexical decisions to the word targets. Note the similarity to the study of Caroll, Lukatela and Turvey (1988) who conducted visual grammatical priming experiments with consciously perceived primes but with less constraining contexts corresponding to Serbo-croatian adjective-noun pairs. Here, the post-hoc analyses revealed that the incongruency context effect was not observed for the pseudoword decision. The grammatical context did not affect the process of rejection of pseudowords.

Crucially for the purpose of our study, no such effects of incongruency were obtained in the subliminal visual priming. Thus, the efficiency of word recognition performance in the pronoun-congruent context relative to the pronoun-incongruent context depended on the conscious perception of the context, as shown by a significant Consciousness (Experiment 2a vs. 2b) and Congruency (congruent vs. incongruent pronoun) interaction on the RTs \( (F_1(1,76) = 3.36, p < .05, F_2(1,106) = 3.70, p < .05) \) and on the error
rates ($F_1(1,76) = 3.44, p < .05, F_2(1,106) = 4.2, p < .05$). Consequently, we have replicated the results of Lukatela et al. (1990), suggesting a post-lexical locus of grammatical context effects. More particularly, the incongruency effect emerges when the participants were consciously processing the primes. While the facilitatory context effect is traditionally assumed to reflect automatic lexical spreading activation, the absence or presence of this effect can also depend on the context-based expectations (see, Deustch & Bentin, 1994). The absence of a facilitatory context effect when the visual prime was perceived consciously could be explained by the shorter temporal interval (approximately 350 ms) between the context and the moment at which the grammatical relevant information (i.e., the verbal inflection) can be processed as compared to the auditory modality in which a longer temporal interval separates the stem and its inflection (for short ISI, stem duration - > 500 ms plus 50 ms ISI). This shorter processing time could reduce the strength of context-based expectations in conscious visual grammatical priming, suggesting that the incongruency effect is the result of post-lexical analysis rather context-based expectations.

4. GENERAL DISCUSSION

To our knowledge, this is the first study which investigates grammatical context effects when the pronominal context can constrain or predict the immediately following target verb. This strong constraining context on the target in French subject-verb person agreement gave us a promising tool for testing for automatic spreading lexical activation from primes to verbal inflected targets. We first compared the priming effect of this strongly constraining context in the auditory modality at two different temporal intervals separating the context and the target word. Then, we explored how these constraining grammatical context effects operate in the visual modality by presenting the prime subliminally.

In the auditory grammatical priming experiment with a short ISI, the congruent context facilitated word recognition, whereas the incongruent context inhibited word recognition. As in previous visual priming experiments (Lukatela, Moraca, Stojnov, Savic, Katz, & Turvey, 1982), an effect of congruency was found. Importantly, however, the grammatical context effects that we observed in auditory grammatical priming with a short ISI did not decrease in size with a longer ISI, but were similar in size. The manipulation of the temporal interval separating the context from the target word is usually employed to dissociate automatic spreading
lexical activation from context-based expectations (Neely, 1991). Longer temporal intervals leave participants more time to generate context-based expectations. However, in case of the auditory modality, the recognition of target’s relevant grammatical information in the case of pronoun-verb agreement comes from the onset of verbal inflection and thus arrives quite late with respect to the stem. This provides the participants with longer temporal intervals between the context and the moment at which the relevant grammatical information becomes available (in our case, more than 500 ms) and this for both ISI conditions. In line with this assumption, no impact of varying ISI was observed on the size of the priming effect in the auditory modality for the processing of grammatical relation morphologically marked at the end of targets, particularly in Serbo-Croatian adjective-nouns agreement relation (Katz, Boyce, Goldstein, & Lukatela, 1987). Interestingly, an additional experiment we conducted with subliminal auditory grammatical priming using a methodology similar to that of Kouider and Dupoux (2005) failed to show any grammatical context effects. Despite the fact the auditory modality has been shown in the literature to reveal automatic spreading lexical activation, our grammatical context effects in this modality do not seem to be produced by automatic lexical processes. Instead, our findings in the auditory modality converge to suggest that the grammatical context effects result from post-lexical processes that would require conscious perception of the context. Hence, neither the sequential physical constraints in the auditory input nor the weight of non-redundant morphological markers in spoken language enable automatic spreading activation from the prime to the inflected targets.

Our second experiment using unmasked visual primes showed an incongruency effect, that is, the grammatically incongruent context produced slower target recognition than the grammatically congruent context did. However, no such effect of context was observed when the prime was presented subliminally. Despite the fact we used contexts that were more conducive than earlier studies for observing automatic spreading lexical activation triggered by the grammatical context, we failed to do so. Our findings thus replicate previous studies conducted with less constraining contexts in the visual modality (Lukatela, Carello, & Turvey, 1990; Lukatela, Moraca, Stojnov, Savic, Katz, & Turvey, 1982). Taken together, all these studies converge in suggesting that grammatical context effects in the visual modality have a post-lexical locus. These findings are also consistent with a more recent visual priming experiment manipulating word category violations and using more sensitive measures with Event-Related Potentials (ERP) which showed
that syntactic brain responses depended on the participants’ awareness and the availability of attentional resources (Batterink, Karns, Yamada, & Neville, 2010). Moreover, it seems that in whatever modality grammatical context is delivered, the grammatical context effects are post-lexical in nature.

Like the effects of grammatical context, semantic priming effects are generally difficult to obtain when the prime is processed unconsciously (for a review, Kouider & Dehaene, 2007). Two other ERP studies also have reported that semantic context effects depended on the conscious perception of the visual primes (Holcomb, Reder, Misra, & Grainger, 2005; Ruz, Madrid, Lupiéñez, & Tudela, 2003). Additionally, an ERP study in dichotic listening found that semantic context effects were observed only in words on which participants focused their attention (Bentin, Kutas, & Hillyard, 1995). This suggests that processing at semantic and grammatical levels is sensitive to conscious access to, and to attentional resources directed at, the incoming words. Even if both semantic and grammatical context effects are dependent upon the conscious perception of context, this does not mean that the semantic and grammatical context effects are totally similar in nature. Note, for example, that semantic context effects can result from expectations of some specific lexical candidates (e.g., teacher can prime school, professor, mentor), while grammatical context effects can be at best due to the expectations of one large set of particular grammatical forms (e.g., all inflected verbs sharing the same morphosyntactic features expressed by the verbal inflection –ons).

Taken together, our study showed clearly that the grammatical context effects with pronominal subject-verb agreements are not driven by automatic spreading lexical activation from the pronominal subject. Rather, our findings provide evidence that the computation of agreement relations operates at a post-lexical locus and requires conscious access to words.

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REFERENCES

Grammatical context effects on word recognition


## APPENDIX

### Word targets

<table>
<thead>
<tr>
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