Eyetracking prediction and ungrammaticality detection in the healthy aging brain

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Introduction: Prediction and ungrammaticality detection are fundamental for efficient language processing (Kuperberg & Jaeger, 2016), but we know little about how they evolve through age. In aging, predictability and grammaticality are influenced by two competing cognitive forces: *crystalized abilities*, such as language experience, and *fluid abilities*, such as working memory capacity (WMC) and processing speed (Reifegerste, 2020; Harada et al., 2013). Accordingly, how does age modulate predictability? Does age influence ungrammaticality detection? If prediction and grammaticality are influenced by language experience (Hypothesis 1), older adults should make better predictions and ungrammaticality should be more salient for them than for younger adults. By contrast, if they are constrained by cognitive factors (Hypothesis 2), older adults should generate worse predictions and ungrammaticality should be less salient for them than for young adults.

Methods. The eye-movement reading patterns of 24 young (Age: 23.1 (3.7)) and 27 senior (Age: 62.2 (4.2)) healthy native Spanish speakers were recorded to investigate the effects of aging in lexical vs. grammatical prediction during a sentence comprehension task. Participants read sentences for meaning with a Verb+Clitic manipulating semantic predictability (high-cloze vs. low-cloze verbs) and grammaticality (grammatical vs. ungrammatical object-clitic gender agreement) (see Figure 1). They had to give yes/no responses to comprehension questions about the meaning of these sentences in 33% of the trials. *First Fixation Durations (in first pass reading, the duration of the first fixation on a word), Fixation Durations (the sum of all fixations on a word prior to moving to another word)*,*Total Fixation Durations (the sum of all fixations on a word, included regressions)*, *Total Visit Durations (the sum of the duration of each fixation within a visit)* and *Probability of Regressions in (the probability of going backwards to previous parts of the sentence or not)* were analyzed in four regions of interest (*Subject*, *Antecedent*, *Verb+Clitic*, *Spillover)*. These measures, by means of the duration of the fixations and the location of the eyes provide direct evidence of predictability (Veldre & Andrews, 2018) and allows to infer agreement encoding processes (Mancini et.al., 2014)

Results and discussion. Only significant effects are discussed. LME analyses ((g)mer(logRT/RegressionProbability ~ group* predictability * grammaticality * WMC + (1 | subject) + (1 | item)) revealed predictability and grammaticality effects for both groups at the Verb+Clitic region, with larger *Total Fixations* and more *Regressions* for low-cloze than for high-cloze verbs and for ungrammatical than for grammatical sentences. An age group by predictability interaction was only found in probability of regressions at the Verb+Clitic region, with larger predictability effects in low-cloze than high-cloze verbs for seniors (see Figure 2). Interestingly, consistent age group by grammaticality interactions were found in most measures and ROIs (see Figure 2), revealing larger fixations and more regressions to the antecedent and spillover regions in ungrammatical than grammatical sentences only for older adults in *Fixation Durations*, *Total Fixation Durations* and *Total Visit Durations*. However, in *Total Visit Durations* at the Verb+Clitic, the grammaticality effect was significant for both groups, although larger for seniors. Thus, although there were no differences in the processing speed between groups (no group effect in any measure), older adults went backwards during sentence processing more often, which might suggest greater attempts at solving the ungrammaticality.

Conclusions. The findings revealed that age modulates language processing, since we obtained differences in the predictability effects by age and a strong distinct pattern for ungrammaticality detection as a function of age increase under similar processing speed for both groups. This novel finding regarding grammaticality aligns with our Hypothesis 1, in which increased language experience as a result of age is beneficial for certain aspects of sentence processing.

Keywords: predictability, ungrammaticality detection, eye-tracker, healthy aging

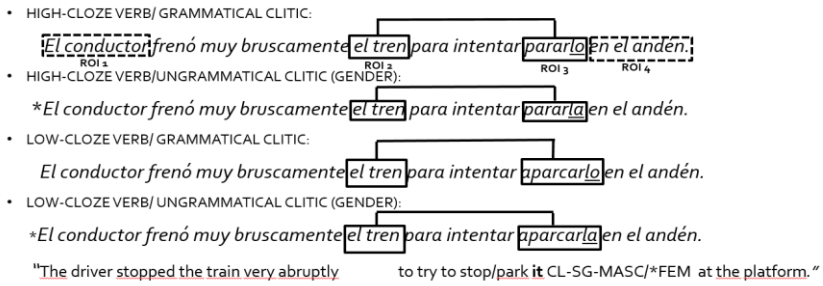

Figure 1. *Sample sentences of an item in the four experimental conditions resulting from the manipulation of predictability (low vs. high-cloze verbs) and grammaticality (grammatical vs. ungrammatical). The 4 ROIs analyzed (subject, object antecedent, verb and spillover) are marked in the first condition. The two regions involved in the dependency relation defining grammaticality (Verb+clitic and antecedent) are highlighted in black across all conditions*.

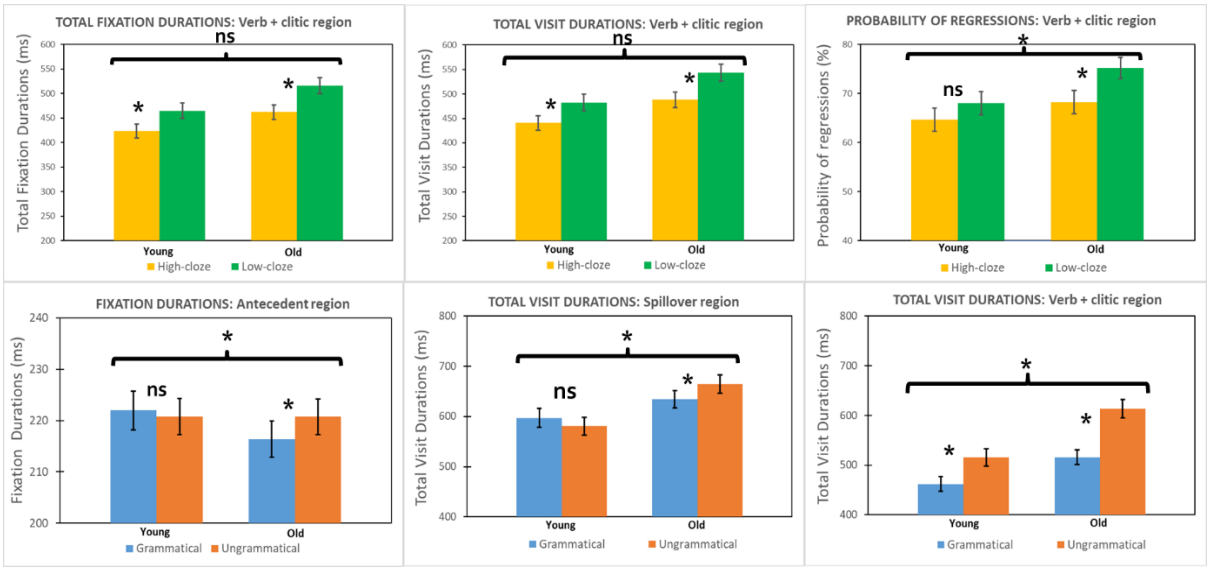

Figure 2. Selection of the most representative predictability and grammaticality by group interactions. UPPER LINE: graphs plotting the predictability by group interactions. *Left graph: significant interaction of predictability by group in probability of regressions at the Verb+Clitic region, with a significant predictability effect only for the seniors (more regressions in low-cloze). Middle and right graphs: non-significant interactions at the Verb+Clitic region for Total Visit Durations and Total Fixation Durations, with the main effects of predictability being significant for both age groups. BOTTOM LINES: Graphs plotting the grammaticality by group interactions. Left and middle graphs: significant grammaticality by group interactions in Fixation Durations and Total Visit Durations at the antecedent and spillover regions with the main effects of grammaticality being significant only for the seniors (larger total fixation durations for ungrammatical sentences). Right graph: significant grammaticality by group interaction in Total Visit Durations at the Verb+Clitic region with the main effect of grammaticality significant for both age groups, but this being larger for the seniors.*

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