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## Warning: package 'dplyr' was built under R version 3.6.2

## Warning: package 'tidyr' was built under R version 3.6.2

## Warning: package 'purrr' was built under R version 3.6.2

## Warning: package 'ggplot2' was built under R version 3.6.2

## Warning: package 'broom' was built under R version 3.6.2

## Warning: package 'broom.mixed' was built under R version 3.6.2

## Warning in checkMatrixPackageVersion(): Package version inconsistency detected.  
## TMB was built with Matrix version 1.2.18  
## Current Matrix version is 1.3.2  
## Please re-install 'TMB' from source using install.packages('TMB', type = 'source') or ask CRAN for a binary version of 'TMB' matching CRAN's 'Matrix' package

## Warning: package 'TMB' was built under R version 3.6.2

## Warning: package 'lme4' was built under R version 3.6.2

## Warning: package 'Matrix' was built under R version 3.6.2

## Warning: package 'AICcmodavg' was built under R version 3.6.2

## Warning: package 'patchwork' was built under R version 3.6.2

# Journal of Memory and Language article (stress, natives and late advanced and intermediate EN y Ma Ch

## Overview

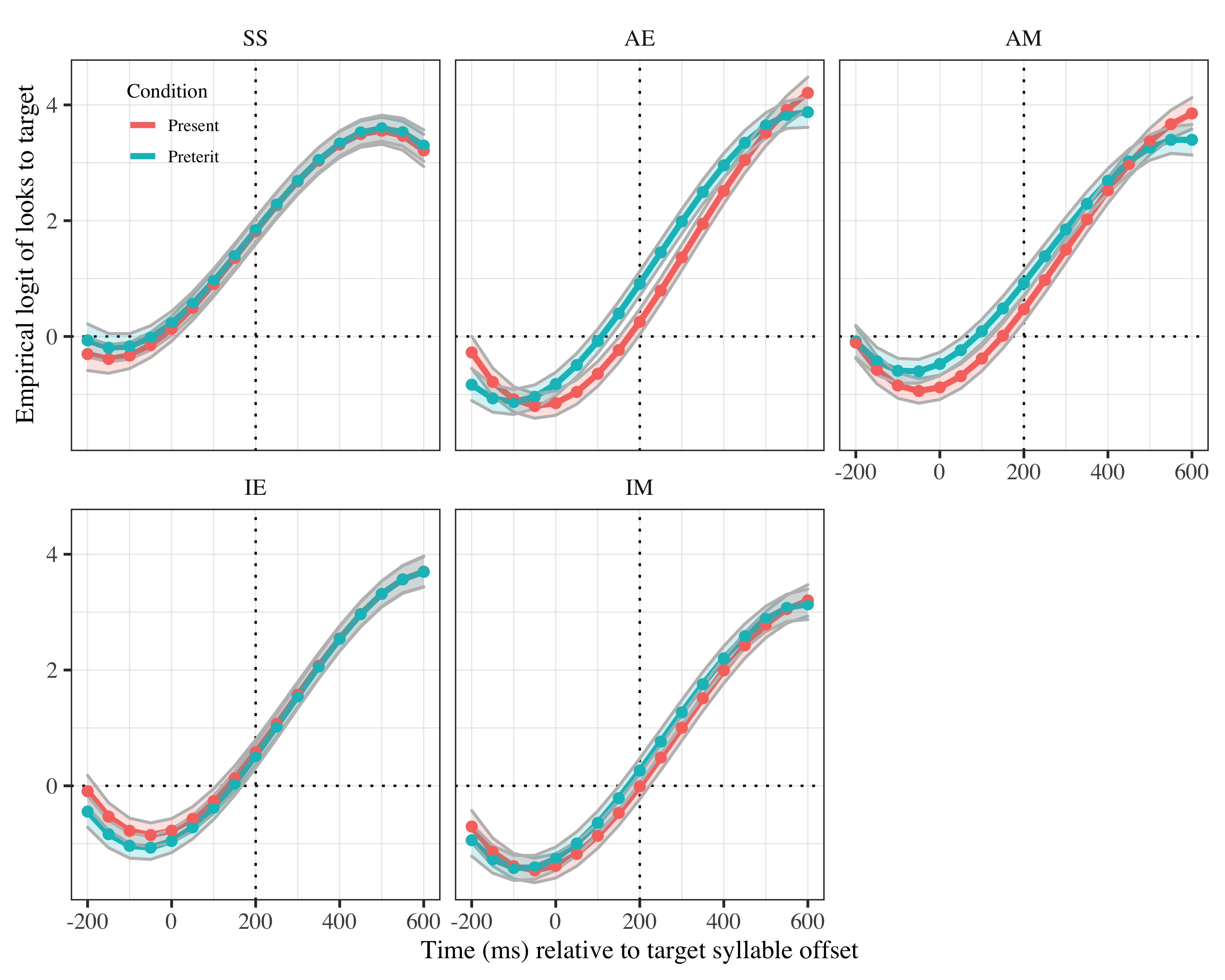
This document contains updates to the statistical analysis for stress\_unrelated experiment (draft for ISB). Last updated on 2021-02-17. The results section can be copied and pasted into the corresponding google doc. The tables can also be copy and pasted where appropriate.

## Main changes

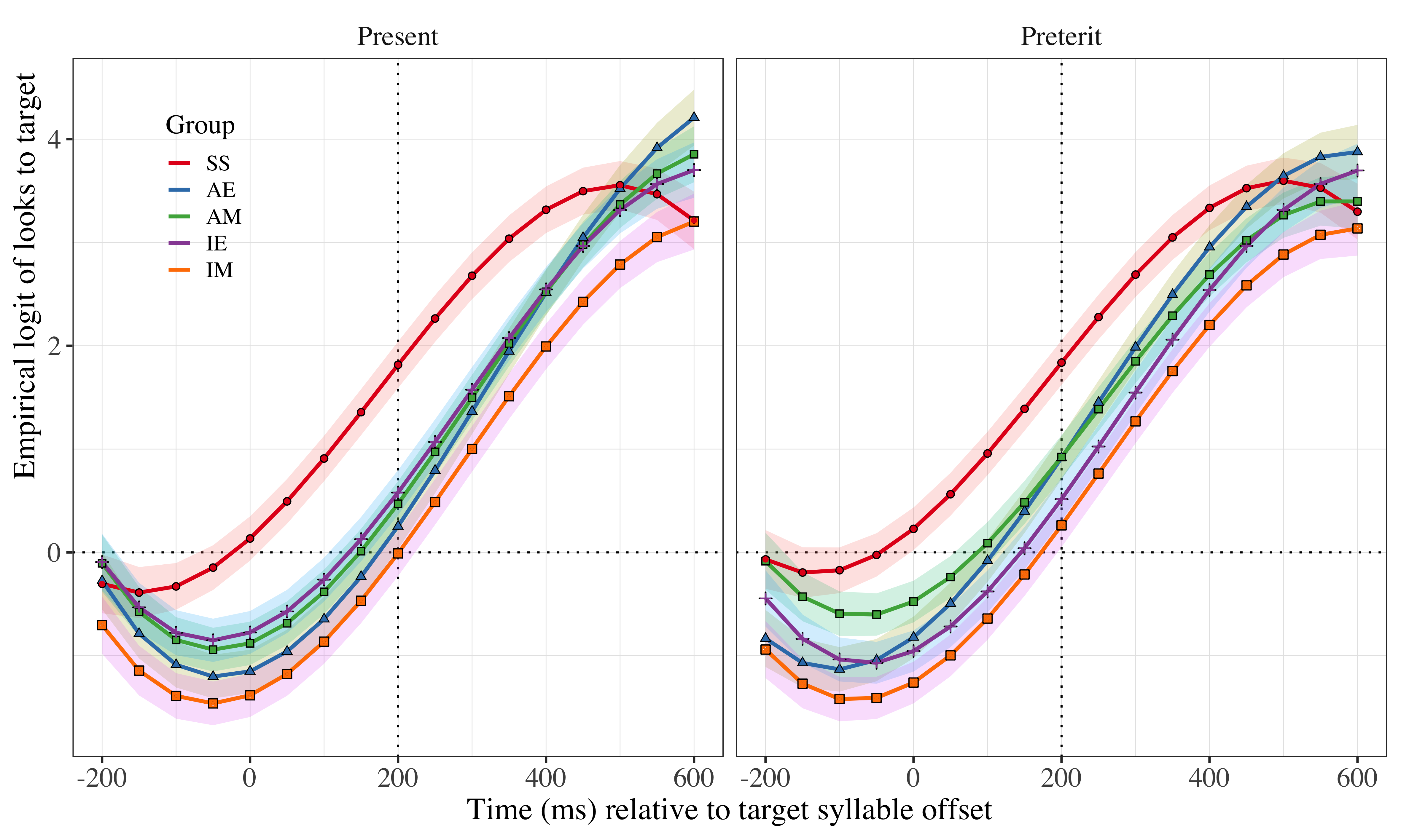
**Participants**

**Analyses**

# Plots



*Figure* *1:*. Growth curve analysis estimates of fixations on target as a function of lexical stress for each group during the analysis window. Lines represent model estimates, and the transparent ribbons represent ±SE. Empirical logit values on y-axis correspond to proportions of 0.12, 0.50, 0.88, and 0.98. The horizontal dotted line represents the 50% probability of fixating on the targets. The vertical dotted line indicates 200 ms. after the offset of the target syllable.



*Figure* *2:*. Growth curve analysis estimates of fixations on the target as a function of lexical stress for each group during the analysis window. Symbols and lines represent model estimates, and the ribbons represent ±SE. Empirical logit values on y-axis correspond to proportions of 0.12, 0.50, 0.88, and 0.98. The horizontal dotted line represents the 50% probability of fixating on the targets. The vertical dotted line indicates 200 ms. after the offset of the target syllable.

# Tables

## Model estimates at target syllable offset

Table 1:

| Group | Lexical stress | Probability | LB | UB |
| --- | --- | --- | --- | --- |
| SS | present | 0.8612882 | 0.8299301 | 0.8876472 |
|  | preterit | 0.8618758 | 0.8319273 | 0.8872113 |
| AE | present | 0.5653278 | 0.5068207 | 0.6220699 |
|  | preterit | 0.7128605 | 0.6643810 | 0.7568996 |
| AM | present | 0.6182037 | 0.5612590 | 0.6720758 |
|  | preterit | 0.7152918 | 0.6670310 | 0.7590841 |
| IE | present | 0.6438652 | 0.5887647 | 0.6954024 |
|  | preterit | 0.6255260 | 0.5716954 | 0.6764203 |
| IM | present | 0.5008632 | 0.4422083 | 0.5594944 |
|  | preterit | 0.5644489 | 0.5081990 | 0.6190874 |

*Table 1*: Model estimates for probability of target fixations ±SE at 200 ms after the target syllable offset. (LB = lower bound; UP = upper bound)

## Fixed effects

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| effect | Parameter | Estimate | SE | *t* | *p* |
| fixed | Intercept (γ00) | 1.717 | 0.149 | 11.488 | < .001 |
| fixed | Time1 (γ10) | 5.856 | 0.440 | 13.312 | < .001 |
| fixed | Time2 (γ20) | −0.408 | 0.319 | −1.279 | .201 |
| fixed | Time3 (γ30) | −1.343 | 0.182 | −7.382 | < .001 |
| fixed | GroupAE (γ01) | −0.698 | 0.178 | −3.921 | < .001 |
| fixed | GroupAM (γ11) | −0.620 | 0.178 | −3.480 | < .001 |
| fixed | GroupIE (γ21) | −0.732 | 0.177 | −4.138 | < .001 |
| fixed | GroupIM (γ31) | −1.198 | 0.178 | −6.730 | < .001 |
| fixed | Lexical stress (γ02) | −0.028 | 0.110 | −0.254 | .799 |
| fixed | Time1 × GroupAE (γ12) | 1.455 | 0.512 | 2.844 | .004 |
| fixed | Time1 × GroupAM (γ22) | 0.342 | 0.512 | 0.669 | .504 |
| fixed | Time1 × GroupIE (γ32) | 0.652 | 0.508 | 1.282 | .200 |
| fixed | Time1 × GroupIM (γ03) | 0.685 | 0.512 | 1.338 | .181 |
| fixed | Time2 × GroupAE (γ13) | 1.997 | 0.417 | 4.795 | < .001 |
| fixed | Time2 × GroupAM (γ23) | 1.861 | 0.417 | 4.466 | < .001 |
| fixed | Time2 × GroupIE (γ33) | 1.997 | 0.414 | 4.825 | < .001 |
| fixed | Time2 × GroupIM (γ04) | 1.830 | 0.417 | 4.391 | < .001 |
| fixed | Time1 × Lexical stress (γ14) | −0.102 | 0.202 | −0.505 | .613 |
| fixed | Time2 × Lexical stress (γ24) | −0.094 | 0.196 | −0.478 | .633 |
| fixed | GroupAE × Lexical stress (γ34) | −0.087 | 0.131 | −0.661 | .508 |
| fixed | GroupAM × Lexical stress (γ05) | −0.064 | 0.131 | −0.491 | .623 |
| fixed | GroupIE × Lexical stress (γ15) | 0.089 | 0.130 | 0.685 | .493 |
| fixed | GroupIM × Lexical stress (γ25) | −0.020 | 0.131 | −0.154 | .878 |
| fixed | Time1 × GroupAE:Lexical stress (γ35) | −0.232 | 0.242 | −0.956 | .339 |
| fixed | Time1 × GroupAM:Lexical stress (γ06) | 0.212 | 0.243 | 0.874 | .382 |
| fixed | Time1 × GroupIE:Lexical stress (γ16) | −0.304 | 0.241 | −1.262 | .207 |
| fixed | Time1 × GroupIM:Lexical stress (γ26) | −0.193 | 0.243 | −0.795 | .427 |
| fixed | Time2 × GroupAE:Lexical stress (γ36) | 0.858 | 0.242 | 3.543 | < .001 |
| fixed | Time2 × GroupAM:Lexical stress (γ00) | 0.560 | 0.243 | 2.310 | .021 |
| fixed | Time2 × GroupIE:Lexical stress (γ10) | 0.174 | 0.241 | 0.720 | .471 |
| fixed | Time2 × GroupIM:Lexical stress (γ20) | 0.386 | 0.243 | 1.592 | .111 |

Appendix 1: Growth curve model fixed effects

## Random effects

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Group | Parameter | Variance | SD | Correlations |  |  |  |  |
| Participant | Intercept | 0.439 | 0.663 | 1.00 |  |  |  |  |
|  | Lexical stress | 0.215 | 0.464 | .08 | 1.00 |  |  |  |
|  | Time1 | 4.760 | 2.182 | .11 | −.01 | 1.00 |  |  |
|  | Time2 | 1.786 | 1.336 | −.29 | −.04 | −.13 | 1.00 |  |
|  | Time3 | 0.867 | 0.931 | −.09 | .12 | −.83 | −.10 | 1.00 |
| Item | Intercept | 0.191 | 0.437 | 1.00 |  |  |  |  |
|  | Time1 | 1.540 | 1.241 | −.41 |  | 1.00 |  |  |
|  | Time2 | 0.389 | 0.624 | −.83 |  | −.05 | 1.00 |  |
|  | Time3 | 0.700 | 0.837 | .39 |  | −.97 | −.02 | 1.00 |
| Residual |  | 14.525 | 3.811 |  |  |  |  |  |

Appendix 2: Growth curve model random effects

## Pairwise comparisons

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| effect | Parameter | Estimate | SE | *t* | *p* |
| fixed | GroupAM (γ08) | 0.078 | 0.175 | 0.448 | .654 |
| fixed | Time1 × GroupAM (γ18) | −1.113 | 0.503 | −2.210 | .027 |
| fixed | Time2 × GroupAM (γ28) | −0.136 | 0.410 | −0.332 | .740 |
| fixed | GroupAM × Lexical stress (γ38) | 0.022 | 0.129 | 0.173 | .863 |
| fixed | Time1 × GroupAM:Lexical stress (γ09) | 0.444 | 0.238 | 1.861 | .063 |
| fixed | Time2 × GroupAM:Lexical stress (γ19) | −0.298 | 0.238 | −1.250 | .211 |

Appendix 3a: Pairwise comparisons between advanced learner groups (AE reference).

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| effect | Parameter | Estimate | SE | *t* | *p* |
| fixed | GroupIM (γ08) | −0.579 | 0.175 | −3.304 | < .001 |
| fixed | Time1 × GroupIM (γ18) | 0.343 | 0.504 | 0.681 | .496 |
| fixed | Time2 × GroupIM (γ28) | −0.031 | 0.410 | −0.076 | .939 |
| fixed | GroupIM × Lexical stress (γ38) | 0.044 | 0.129 | 0.343 | .732 |
| fixed | Time1 × GroupIM:Lexical stress (γ09) | −0.405 | 0.239 | −1.696 | .090 |
| fixed | Time2 × GroupIM:Lexical stress (γ19) | −0.174 | 0.239 | −0.729 | .466 |
| Appendix | 3b: Pairwise comparisons between Mandarin Chinese learner groups | (AM reference) | . |  |  |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| effect | Parameter | Estimate | SE | *t* | *p* |
| fixed | GroupIE (γ08) | −0.033 | 0.174 | −0.193 | .847 |
| fixed | Time1 × GroupIE (γ18) | −0.803 | 0.500 | −1.606 | .108 |
| fixed | Time2 × GroupIE (γ28) | −0.000 | 0.407 | −0.000 | 1.000 |
| fixed | GroupIE × Lexical stress (γ38) | 0.176 | 0.128 | 1.374 | .169 |
| fixed | Time1 × GroupIE:Lexical stress (γ09) | −0.073 | 0.237 | −0.308 | .758 |
| fixed | Time2 × GroupIE:Lexical stress (γ19) | −0.685 | 0.237 | −2.887 | .004 |
| Appendix | 3c: Pairwise comparisons between EN learners (AE reference). |  |  |  |  |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| effect | Parameter | Estimate | SE | *t* | *p* |
| fixed | GroupIM (γ08) | −0.467 | 0.174 | −2.685 | .007 |
| fixed | Time1 × GroupIM (γ18) | 0.033 | 0.500 | 0.067 | .947 |
| fixed | Time2 × GroupIM (γ28) | −0.167 | 0.407 | −0.411 | .681 |
| fixed | GroupIM × Lexical stress (γ38) | −0.110 | 0.128 | −0.854 | .393 |
| fixed | Time1 × GroupIM:Lexical stress (γ09) | 0.112 | 0.237 | 0.470 | .638 |
| fixed | Time2 × GroupIM:Lexical stress (γ19) | 0.212 | 0.237 | 0.895 | .371 |
| Appendix | 3d: Pairwise comparisons between intermediate learner groups (IE | reference). |  |  |  |

# 5. Results

SS speakers results are presented first, followed by comparisons between L2 groups. The summary for the full model of the Growth Curve Analysis is in the Appendices 2 and 3. The model also estimated the probability of fixations on the target at the offset of the first syllable in the verb; the probabilities were estimated for each group in both lexical stress conditions (see Table 1; stressed syllable = present, unstressed syllable = preterit). These probabilities are contained in Table 1.

The model intercept estimates the log odds of SS fixating their gaze on the target averaging across lexical stress condition and time course (*γ*00 = 1.717, SE = 0.149. *t* = 11.488, *p* = < .001) with a probability of 0.86 (LB = 0.83, UB = 0.89) in the present tense and of probability = 0.86 (LB = 0.83, UB = 0.89) in the preterit tense. The value for the intercept along with the probabilities suggest that SS were anticipating correctly.

There was a main effect of group indicating that L2 speakers predicted less than SS (AE: *γ*01 = −0.698, SE = 0.178. *t* = −3.921, *p* = < .001; AM: *γ*11 = −0.620, SE = 0.178. *t* = −3.480, *p* = < .001; IE: *γ*21 = −0.732, SE = 0.177. *t* = −4.138, *p* = < .001; IM: *γ*31 = −1.198, SE = 0.178. *t* = −6.730, *p* = < .001). The two fit plots in Figure 3 reflect this trend in both tenses. The estimates for the intercept demonstrate that IM was the group that most differed from SS in their ability to anticipate. As seen in Figure 3, the fixation log odds for SS crosses the intercept at a higher point than the log odds for the L2 groups, indicating that SS were fixating more on the target verb at the offset of the first syllable. The estimated probabilities suggest nonetheless that all L2 groups were still anticipating, except for IM in the present tense (AE x present: probability = 0.57, LB = 0.51, UB = 0.62; AE x preterit: probability = 0.71, LB = 0.66, UB = 0.76; AM x present: probability = 0.72, LB = 0.67, UB = 0.76; AM x preterit: probability = 0.62, LB = 0.56, UB = 0.67; IE x present: probability = 0.64, LB = 0.59, UB = 0.70; IE x preterit: probability = 0.63, LB = 0.57, UB = 0.68; IM x present: probability = 0.50, LB = 0.44, UB = 0.56; IM x preterit: probability = 0.56, LB = 0.51, UB = 0.62).

There was also a main effect of the linear term and of the cubic term (*γ*10 = 5.856, SE = 0.440. *t* = 13.312, *p* = < .001; *γ*30 = −1.343, SE = 0.182. *t* = −7.382, *p* = < .001, respectively). These two effects indicate that the slopes were bowed differently across groups—slopes were steeper and bows more closed in the L2 groups (see Fig. 3). The interactions in the linear and cubic polynomial time terms reflect the sigmoid shape of the time course and were retained in the model because they improved the model fit (*β* = 16.939, *df* = 4, *p* = .002). Keeping these interactions yielded an effect caused by the group AE in the linear term (*γ*12 = 1.455, SE = 0.512. *t* = 2.844, *p* = .004), revealing that AE increased their gaze fixations on the target faster than any other group once they started anticipating (see Fig. 3). There was also an effect of all groups in the quadratic term (AE: *γ*13 = 1.997, SE = 0.417. *t* = 4.795, *p* = < .001; AM: *γ*23 = 1.861, SE = 0.417. *t* = 4.466, *p* = < .001; AE: *γ*33 = 1.997, SE = 0.414. *t* = 4.825, *p* = < .001; AM: *γ*04 = 1.830, SE = 0.417. *t* = 4.391, *p* = < .001) that indicates that the quadratic curve was more bowed for the L2 speakers, reflecting that all L2 groups predicted later than SS.

Keeping the term interactions also yielded a more complex interaction effect in the quadratic term between AE and lexical stress (*γ*36 = 0.174, SE = 0.241. *t* = 0.720, *p* = .471) and between AM and lexical stress (GroupAM x Lexical stress: *γ*00 = 0.386, SE = 0.243. *t* = 1.592, *p* = .111). This interaction shows that advanced L2 learners fixated more on the target in the preterit tense than they did in the present tense (see Fig. 4). This increased number of fixations reveals that preterit tense may be easier to anticipate than present tense. Figure 4 reflects the anticipation abilities difference in the advanced groups in the preterit tense towards the present tense. This difference consists of earlier increased fixations on the target verb in the preterit tense upon hearing a lexically unstressed syllable and is represented in the figure by the shift of the preterit tense line to the left in comparison to the present tense line.

Pairwise comparisons compares performance across L2 groups. The pairwise comparisons are in Appendices 4 (advanced groups), 5 (intermediate groups), 6 (English groups) and 7 (Mandarin groups). Comparing speakers of the same L1 across proficiency, there is only a difference in the quadratic term for the L1 English speakers (*γ*19 = −0.685, SE = 0.237. *t* = −2.887, *p* = .004), such that IE anticipate less than AE in the preterit tense. As for L1 Mandarin Chinese speakers, there is only an effect on the intercept, where IM is shown to predict less than AM averaging across time course and stress conditions (*γ*08 = −0.579, SE = 0.175. *t* = −3.304, *p* = < .001). That is, AM predict better overall than IM. Comparing speakers of different L1s with similar proficiency, there was a significant effect on the intercept between IE and IM, such that IE had a higher fixation rate on the target than IM, indicating higher prediction in IE (*γ*08 = −0.467, SE = 0.174. *t* = −2.685, *p* = .007). At advanced proficiency, there was an effect of group on the linear term, demonstrating that AM increased their fixations on the target less steeply than AE in both stress conditions (−1.113, SE = 0.503. *t* = −2.210, *p* = .027).

The data in this study revealed that all groups except IM anticipated. SS was the group that anticipated most and the earliest. Within-group performance was similar across tense conditions for the intermediate groups and SS. For both advanced groups, preterit tense was easier to anticipate than present. Over proficiency, Mandarin speakers improved their prediction ability; English speakers improved overall although the anticipation performance difference is smaller.