Electrophysiological Measurements of Letter-Sound Correspondence in a Low-Functioning Individual with Autism

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Introduction

Learning to read is difficult because of the arbitrary mappings between letters and sounds. With extensive experience, typically developing children acquire the ability to read; over time this becomes a relatively automatic process. However, in certain populations, this ability remains a challenge.

Individuals with autism show various forms of language impairment. Our lab has been working with a low-functioning, non-verbal individual with autism, AI (not his real initials), on assessing and improving his capacity for speech and language. AI received 2 years of explicit letter-sound association training. Although he showed overall improvement on behavioral measures of letter-sound correspondence mapping, AI's performance across testing sessions was inconsistent, making assessment of the success of this intervention difficult. Here we use EEG to assess his knowledge of letter-sound associations using an implicit paradigm that does not rely on overt behavioral responses.

In ERP paradigms, the N400 effect reflects semantic integration: a larger N400 amplitude (a centro-parietal negativity occurring approx. 300-500ms post-stimulus) is elicited by stimuli that are semantically incongruent with their preceding context compared to congruent stimuli (Kutas & Federmeier, 2011). A later positive component (LPC) is also sometimes observed following the N400, such that incongruent conditions are more positive than congruent; this may reflect semantic reanalysis when integration fails (e.g. van de Meerendonk et al., 2008).

The N400 can be used as an implicit measure of vocabulary knowledge in normal adults (Ledoux et al., accepted pending revision): an N400 congruency effect is elicited for known words but not for unknown words. Here, we extend this N400 congruency paradigm to single letters and their corresponding sounds. An initial experiment with normal adults (Coderre et al., 2013) demonstrated an N400 effect from 250-500ms and an LPC effect from 600-800ms over centro-parietal sites. For AI, we predicted N400 and LPC effects for trained letters but not for untrained letters.

Methods

Participant
➢ ~25 years of age
➢ Explicit letter-sound training for 2 years (2010-2012)
  ➢ 15 original trained letters: **b, d, f, h, j, i, m, n, p, s, t, v, w, x, z**
  ➢ 4 letters added after 1.5 years (not analyzed here): **g, k, o, u**
  ➢ 7 untrained letters (not selected for training because of more variable sound mappings): **a, c, e, l, q, r**
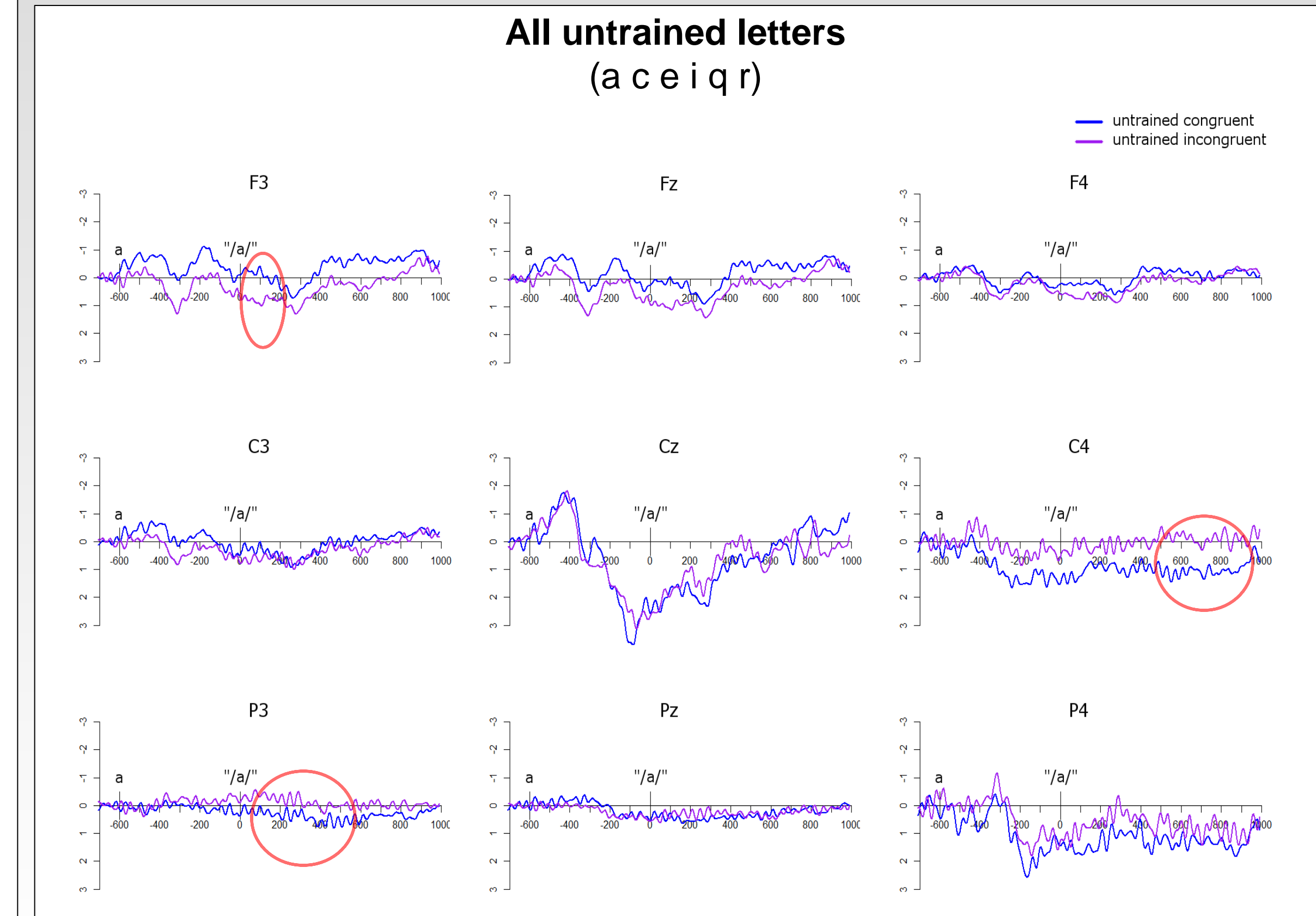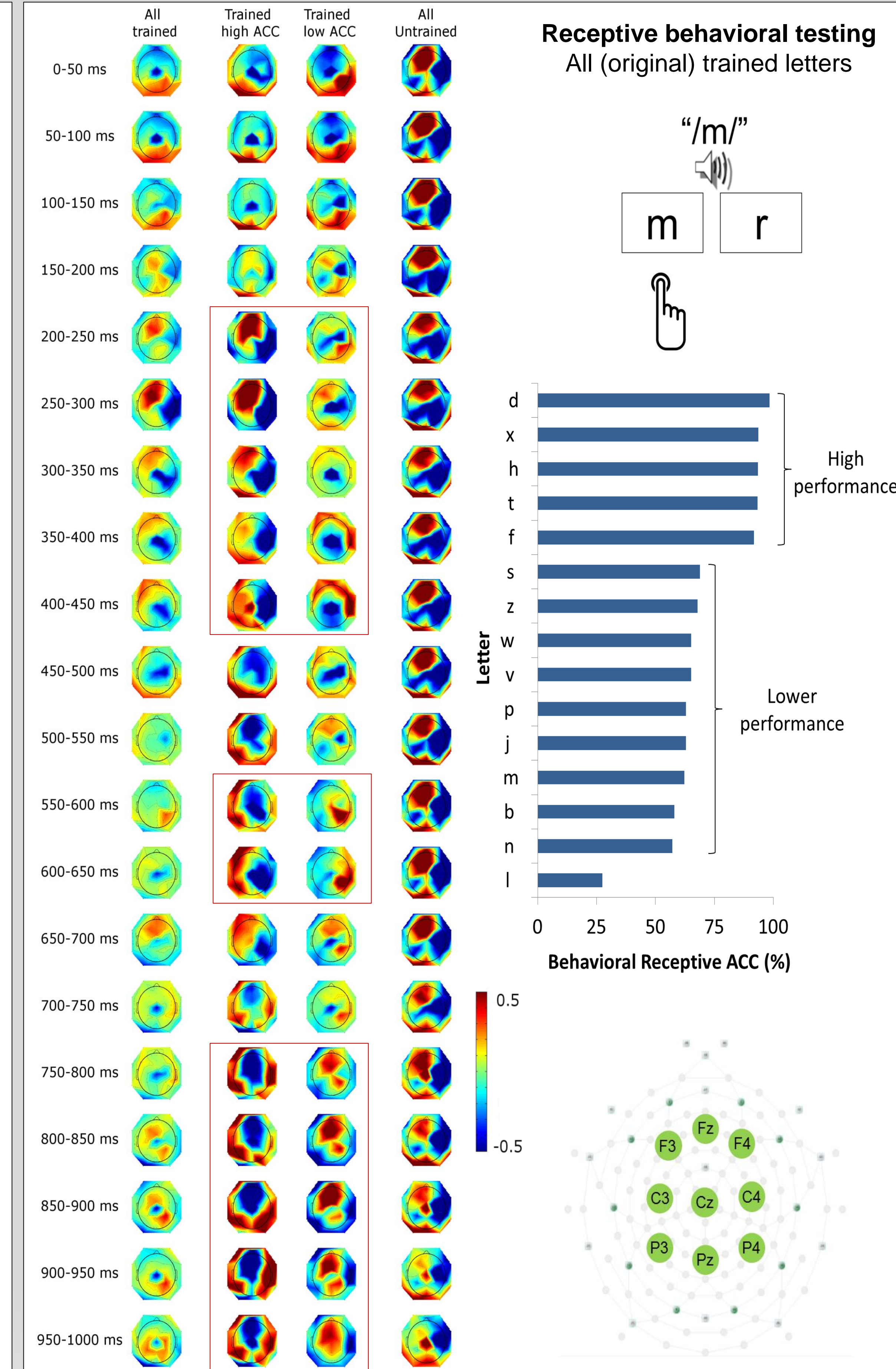
Stimuli:
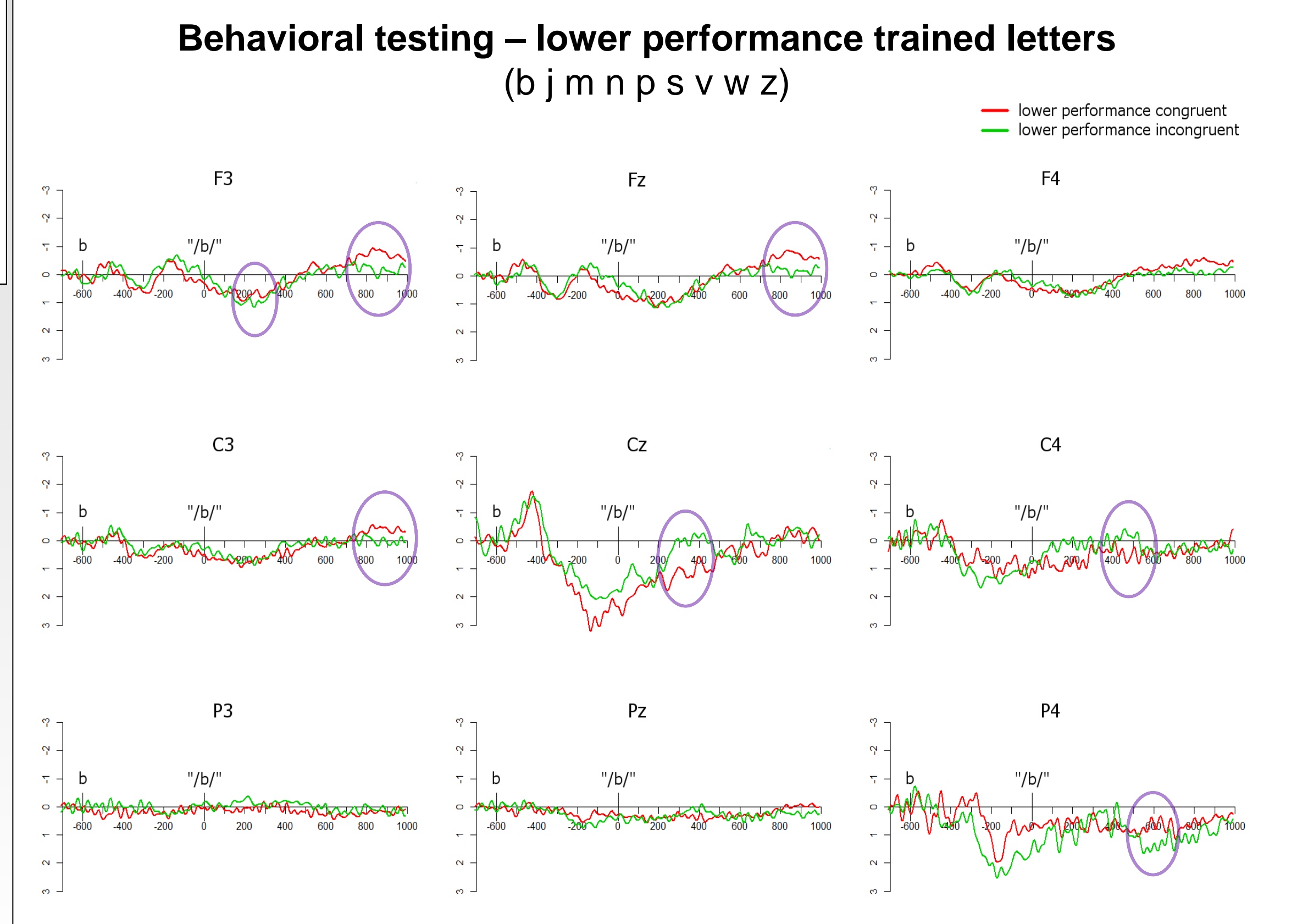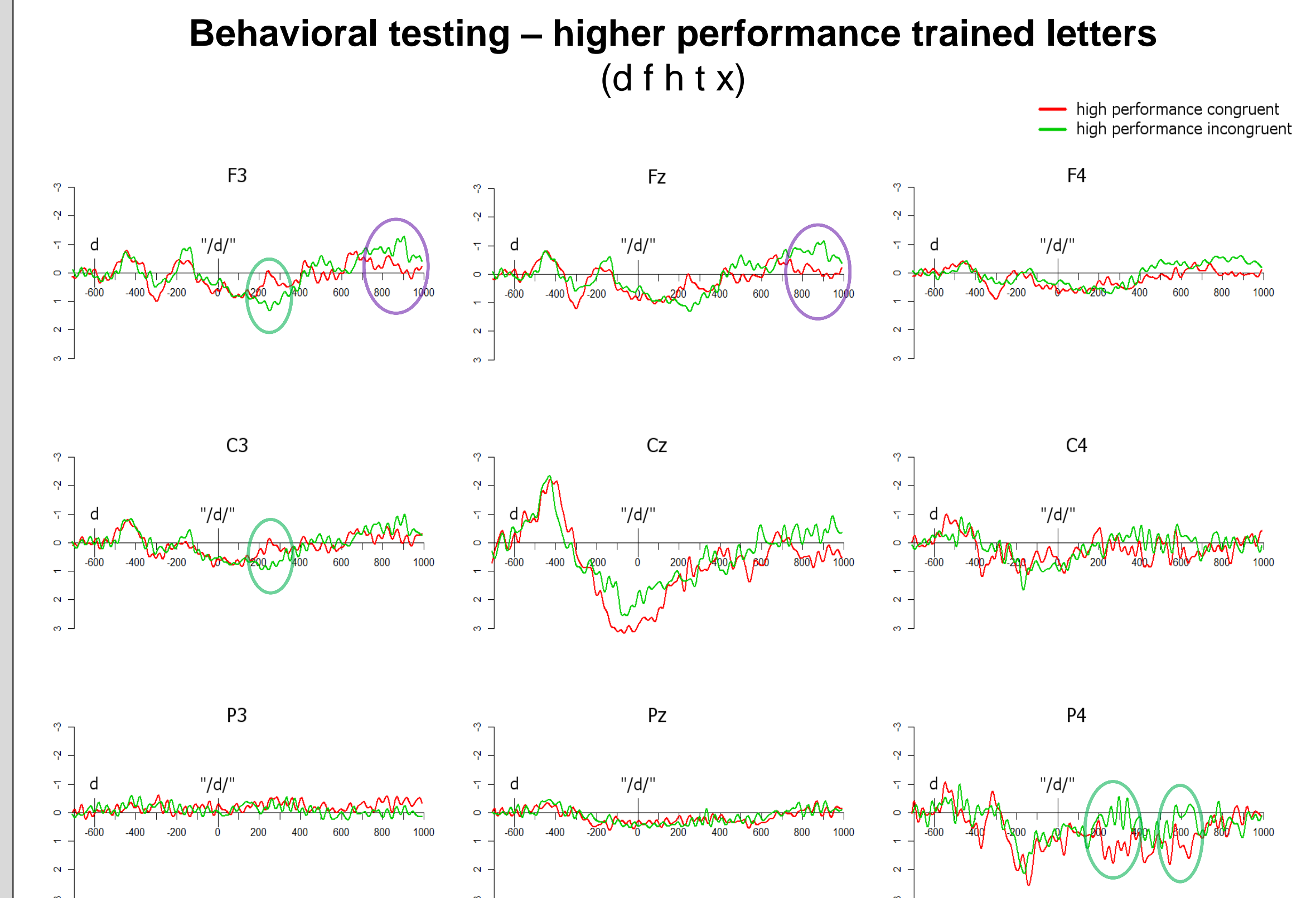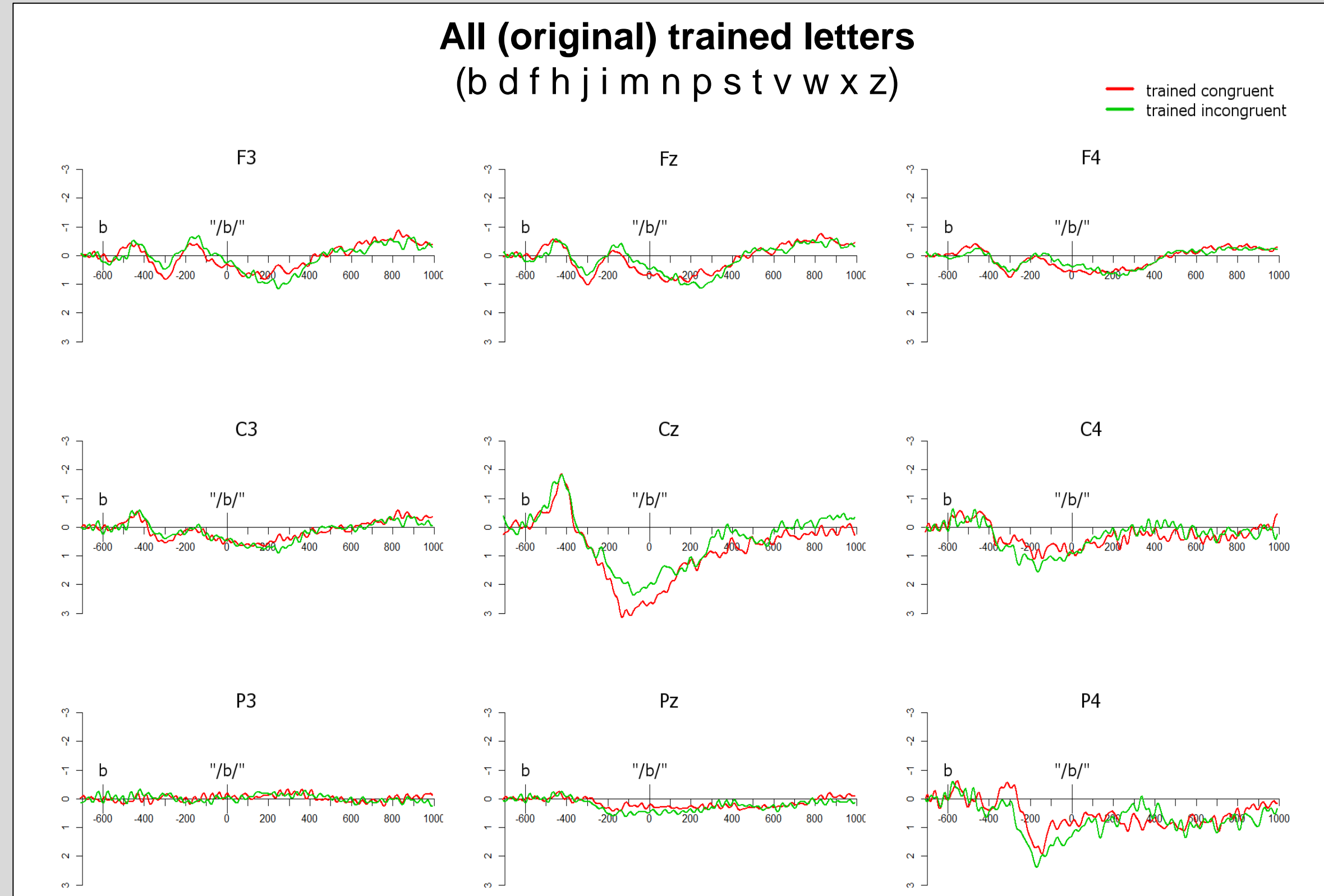➢ 26 letters of the English alphabet
➢ 26 auditory phonemes:
  a, /æ/; b, /b/; c, /k/; d, /d/; e, /ɛ/; f, /f/; g, /g/; h, /h/; I, /I/; j, /dʒ/; k, /k/; l, /l/; m, /m/; n, /n/; o, /o/; p, /p/; q, /k/; r, /r/; s, /s/; t, /t/; u, /u/; v, /v/; w, /w/; x, /ks/; y, /j/; z, /z/.
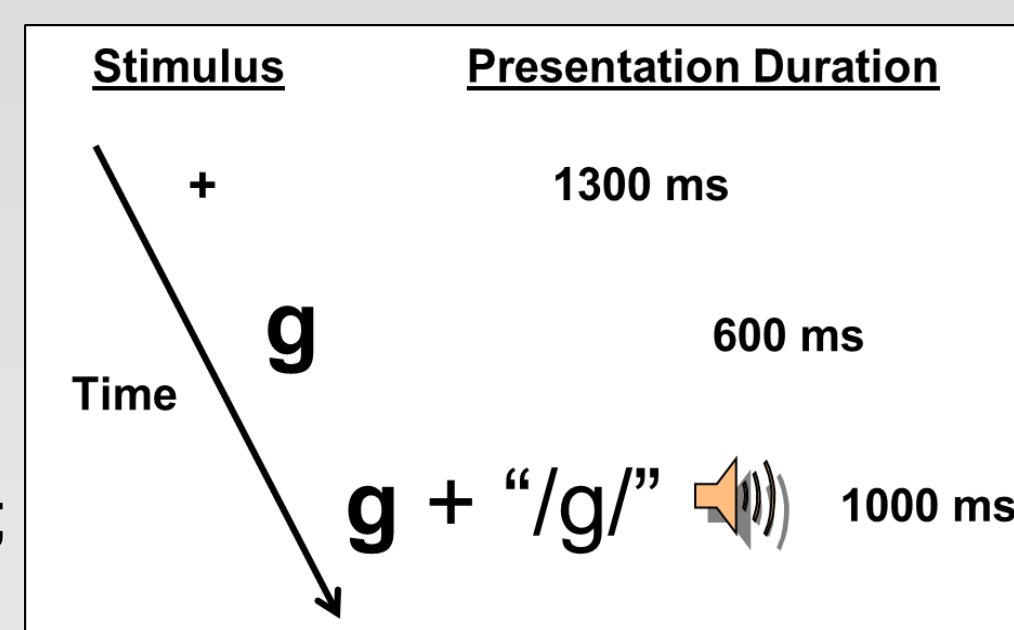
Procedure:
➢ Letter presented for 600ms, followed by presentation of letter and phoneme. No behavioral task required.
➢ 50 blocks tested over 8 sessions, each block including 52 randomly-presented trials (26 congruent letter-phoneme pairs, 26 incongruent)
➢ EEG recorded at 1000 Hz using an Electrical Geodesics Inc. GES 300 with a 32-channel Hydrocel Geodesic Sensor Net and NetStation 4.5.
➢ Motion and eye movement artifacts removed using ICA decomposition. Other bad trials manually removed by visual inspection.
➢ Statistical analyses performed using permutation tests; approximate windows of significance (p < 0.05 using cluster-based FWE correction) indicated with circles.

Results

All (original) trained letters
(b d f h j i m n p s t v w x z)

Behavioral testing – higher performance trained letters
(d f h t x)

Behavioral testing – lower performance trained letters
(b j m n p s v w z)

Receptive behavioral testing
All (original) trained letters

"/m/"

All untrained letters
(a c e i q r)

Discussion

Trained Letters:
When analyzing all trained letters together, there was a trend of an N400 effect at Cz but no LPC effect.

The data were also analyzed based on accuracy (ACC) on receptive behavioral testing administered over the course of training. In this paradigm, AI was asked to identify the spoken letter from two possible visual letter choices. His cumulative accuracy over the training period was used to split the data into two groups of letters: "high performance" (>90% ACC) and "low performance" (50-70% ACC).

High performance trained letters showed an N400 effect (incongruent more negative than congruent) over right parietal scalp from approx. 200-350ms. This effect was slightly delayed and had a different scalp topography in lower performance letters, emerging at approx. 350-450ms over centro-parietal scalp. This could indicate difficulties with semantic integration in lower-performance letters.

Higher- and lower-performance letters showed opposite later effects. From approx. 750-1000ms over frontal scalp, incongruent conditions were more *negative* than congruent conditions for high performance letters but more *positive* than congruent conditions for lower performance letters. These opposite effects could indicate different cognitive processes subserving the recognition of these letter-sound pairs.

Untrained Letters:
Untrained letters showed large separation between the conditions throughout the course of the trial. However, these letters did not show any differences at the same time windows or sites found for trained letters.

Additional Considerations:
All previous work on the N400 in ASD has been performed with high-functioning individuals with autism (HFAs); therefore it is difficult to know what to predict in low-functioning individuals. For example, the N400 and LPC usually show a bilateral centro-parietal scalp distribution, whereas many of the significant effects seen here were over frontal scalp. Data from Pijnacker et al. (2010) suggest a more frontal LPC effect for HFAs compared to normal controls and individuals with Asperger's, which may support this finding.

Conclusions

Overall, these results indicate that trained letters showed different patterns of N400 and LPC effects than untrained letters, indicating some learning as a result of the teaching intervention. This suggests that this congruency paradigm can be used to assess implicit knowledge of letter-sound mappings, even in a single subject. This paradigm could be used to evaluate teaching interventions in low-functioning individuals or beginning readers.

References

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