Electrophysiological correlates of internal performance monitoring in typed language production

Pinet, S.1, & Nozari, N.1,2

1. Department of Neurology, Johns Hopkins University; 2.Department of Cognitive Science, Johns Hopkins University

Monitoring in spoken production can be accomplished via two channels: (a) an internal channel independent of overt auditory feedback, and (b) an external channel which processes the auditory feedback. The relative contribution of these two channels to monitoring is still debated. Complete blockage of the external channel in spoken production is challenging due to bone conduction. In typing, however, visual feedback can be easily suppressed. This study assesses the sufficiency of the internal channel by comparing behavioral and electrophysiological data during typing with and without immediate visual feedback.

Behavioral and EEG data were collected from 17 neurotypical young adults while they typed 352 7-9 letter words from dictation under time pressure. Visual feedback was either delayed (experimental condition) or presented immediately during typing (control condition). In the experimental condition, participants were asked to judge the accuracy of their response after each trial (*metacognitive judgement*), before delayed visual feedback was presented.

We collected 809 errors in the experimental and 872 errors in the control conditions. The availability of visual feedback did not impact accuracy (experimental: 72.9 ± 19%, control: 70.9 ± 15%, $t(16) = 0.79$, $p = 0.44$), response latencies (experimental: 337 ± 40, control: 324 ± 45, $t(16) = 1.15$, $p = 0.27$), or typing speed (experimental: 144 ± 18 ms /keystroke, control: 140 ± 23 ms /keystroke, $t(16) = 1.42$, $p = 0.17$). However, a significantly lower percentage of errors was self-corrected in the experimental (8%) compared to control (46%) condition ($t(16) = -5.1$, $p = 0.001$). This discrepancy might imply that error detection in typing is heavily dependent on visual feedback. But metacognitive reports in the experimental condition showed that participants were aware of 51.9% of their errors (hit rate), and rarely detected a correct response as an error (4.6%

false alarm; d’ = 1.7). The latter finding points to an efficient internal channel for error detection.

To examine how information from the internal (metacognitive judgments) and external (visual feedback) channels is combined, we analyzed the EEG signal at the time of feedback presentation, after metacognitive judgments. Feedback (correct/incorrect response) modulated a positive fronto-central component from 200 ms post feedback presentation. The effect of metacognitive judgments showed an interaction with feedback from 500 ms, creating four distinct waveforms, corresponding to correct rejections, hits, misses and false alarms with increasing positivity over centro-parietal electrodes. These results suggest that monitoring sequentially combines information from both external and internal channels.

In summary, our behavioral results showed that even though correction rate was much lower with delayed visual feedback, error awareness rate in the absence of visual feedback matched the correction rate when visual feedback was immediate. These findings suggest that the internal channel is sufficient for error “detection”, but error “correction” in typing depends heavily on the external channel. Post-feedback EEG results showed a clear pattern of combined sensitivity to information from both external and internal channels. These results constitute the first demonstration of EEG correlates of metacognitive awareness in language production.