Electrophysiological correlates of internal performance monitoring in typed language production

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Introduction

- Monitoring in spoken production relies on both external and internal channels (Levelt, 1983):
  - External channel monitors the auditory input from the articulated word.
  - Internal channel can monitor cognitive processes before the word is articulated.
- Their contribution to detection and correction remains debated, because blocking the external channel during speaking is incomplete due to bone conduction. But it can be complete in typing, if one delays visual feedback.
- EEG indices of performance monitoring:
  - **ERN** (Gehring et al., 1993): Considered an index of internal monitoring, independent of conscious awareness of errors.
  - **Pe** (Falkenstein et al., 2000): Considered an index of conscious awareness of errors or metacognitive judgments.

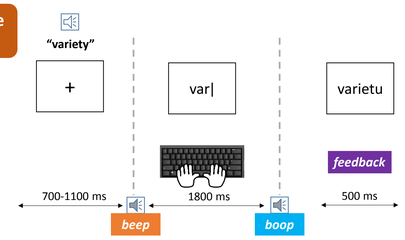
  Both can be used as indices of error detection.

Research questions:

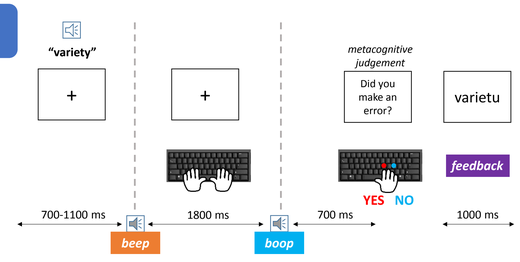
1. Does detection, correction, or both rely on the external channel?
   - *Compare performance in the presence or absence of visual feedback.*
2. Does removal of the external monitoring channel change the timeline of internal monitoring?
   - *Compare the ERN and the Pe in the presence or absence of visual feedback.*
3. When both channels are available, is information from only one or both used?
   - *Use Signal Detection Theory to predict the number of EEG waveforms if information from one or both channels was processed.*

Method

Immediate feedback



Delayed feedback

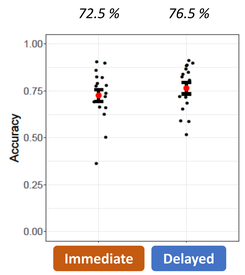


- Dictation task under time pressure
- Immediate vs. Delayed visual feedback
- In delayed, metacognitive judgement first
- 16 proficient typists (86 wpm on average)
- 7-9 letter words (176 x 2)

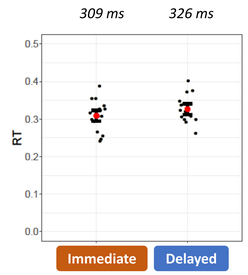
References Falkenstein, M., Hoormann, J., Christ, S., & Hohnsbein, J. (2000). ERP components on reaction errors and their functional significance: A tutorial. *Biological Psychology*, *51*(2–3), 87–107 - Gehring, W. J., Goss, B., Coles, M. G. H., Meyer, D. E., & Donchin, E. (1993). A neural system for error detection and compensation. *Psychological Science*, *4*(6), 385–390 - Hartsuiker, R. J., & Kolk, H. H. J. (2001). Error monitoring in speech production: A computational test of the perceptual loop theory. *Cognitive Psychology*, 42(2), 113–157 - Levelt, W. J. M. (1983). Monitoring and self-repair in speech. *Cognition*, 14, 41–104 - Nozari, N., Dell, G.S., Schwartz, M.F., 2011. Is comprehension necessary for error detection? A conflict-based account of monitoring in speech production. *Cognitive Psychology*. 63, 1–33

Results - Behavior

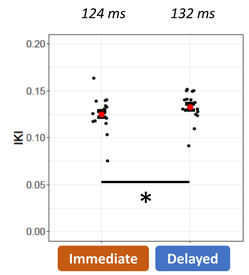
Accuracy



Reaction Times



Typing speed (IKI)



Error Correction vs. Error Detection

Applying the Signal Detection Theory (SDT) to monitoring (Nozari et al., 2011)

	No error detected	Error detected
Correct	*Correct rejection*	*False alarm*
Error	*Miss*	*Hit*

Immediate feedback

	No error corrected	Error corrected
Correct	2043 (99%)	11 (1%)
Error	408 (**54%**)	354 (46%)

Delayed feedback

	No error corrected	Error corrected
Correct	2153 (99.6%)	8 (0.4%)
Error	593 (91%)	62 (9%)

Metacognitive judgements

	No error detected	Error detected
Correct	2065 (96%)	96 (4%)
Error	300 (**46%**)	355 (**54%**)

- Error detection can be independent of the external channel.
- Error correction relies more heavily on the external channel.

Discussion

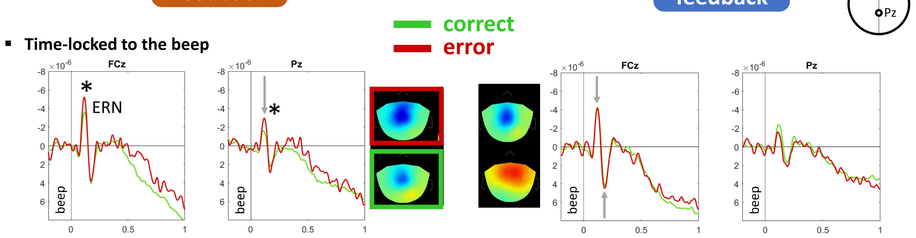
- Error detection and correction can be dissociated at the behavioral level
  - Error detection does not seem to rely on the contribution of the external channel
  - Error correction, however, is dependent on the external channel
- Removing the external channels changes the timeline of internal monitoring: Both the ERN and the Pe appear later in the absence of the external channel.
- Brain keeps track of both sources of information obtained from internal and external channels.

Results - EEG

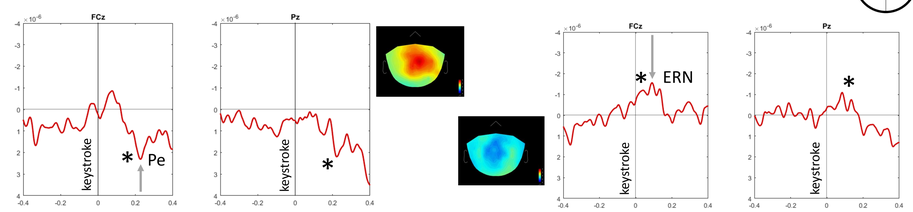
ERN and Pe

Immediate feedback **Delayed feedback**

- **Time-locked to the beep**

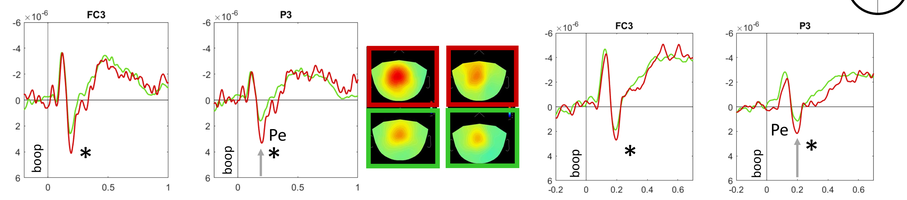


- **Time-locked to the error keystroke corrected for different baselines (hence the difference waveform)**



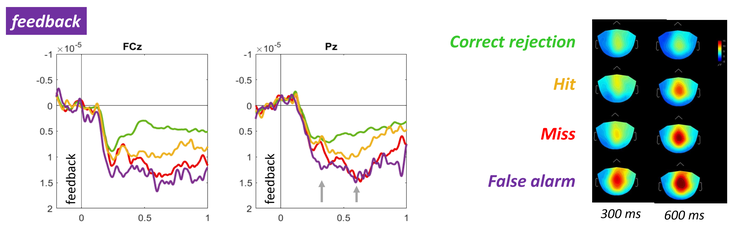
difference between error and correct trials

- **Time-locked to the boop**



Information integration from the two channels in SDT framework

Delayed feedback



Summary

	beep	keystroke	*boop*	Detection	Correction
Immediate feedback	ERN	Pe	Pe	✓	✓
Delayed feedback	Ø	ERN	Pe	✓	✖