Language Output Monitoring in Sign Production: an Electroencephalography Study

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Introduction

A domain-general monitoring mechanism is proposed to be involved in overt speech monitoring [1,2]. This mechanism is reflected in a medial frontal component, the error negativity (Ne), present in both errors and correct trials (Ne-like wave) but larger in errors than correct trials. In overt speech production, this negativity starts to rise before speech onset and is therefore associated with inner speech monitoring [2].

But little is known of the neurophysiological basis of sign language output monitoring.

Here, we investigate whether the same monitoring mechanism is involved in sign language production, before sign production onset.

In addition, we investigate the type of linguistic representations monitored by this medial frontal mechanism using a picture-word interference task manipulating the semantic relationship between the distractor word and the picture (e.g.,[3]).

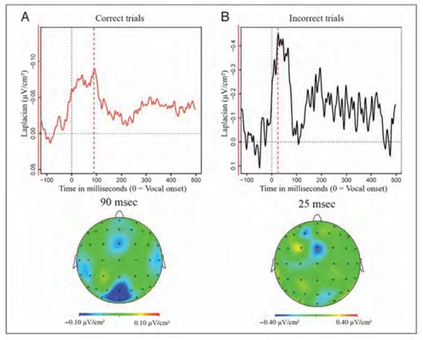
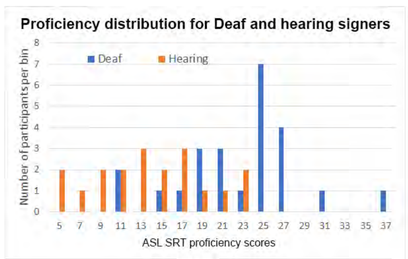


Figure from [2]

Methods

Participants:

- Total of 46 participants (mean age = 34.7 yrs, SD = 9.5 yrs): 26 Deaf (ASL native or early exposed), 20 hearing (ASL native or late exposed).
- The data from 13 Deaf participants and 5 hearing participants was excluded for the Ne/Ne-like wave analysis because <5 error trials remained after artifact rejection OR participant broke task protocol. For the post-hoc analysis of task condition in the Deaf group, the data of only 3 participants was excluded.
- ASL-Sentence Repetition Task (SRT) used to assess signing skills: Subjects view an ASL sentence and then sign back what was just viewed. Sentence complexity and length increased after each trial. In our sample, Deaf participants demonstrated higher proficiency scores than hearing signers, in agreement with [4].



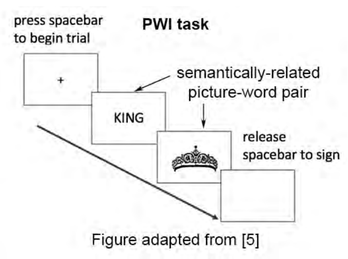


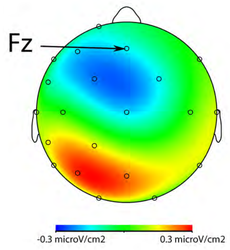
Figure adapted from [5]

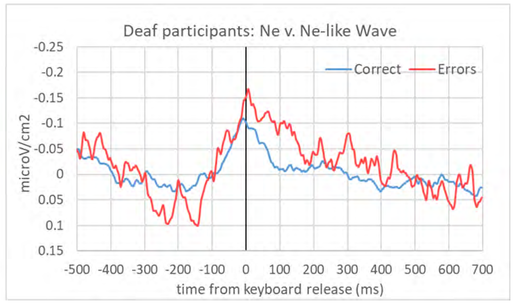
Task:
Picture-word interference task: 50 identical prime-pictures (I, e.g., DEER-deer), 50 semantically related prime-pictures (SR, e.g., KING-crown), and 100 semantically unrelated prime-pictures (U, e.g., PLIERS-necklace). Stimulus onset asynchrony = 200 ms. Behavioral results analyzed using linear (for RTs) and generalized (for accuracy rates) mixed effect models controlling for random effects of participant and picture and by-participant random slopes for picture-word type (I, SR, U) for RT analysis (model did not converge when random slope included for accuracy rate analysis). Only real errors included in error analyses (i.e., hesitations excluded).

EEG:
32 electrodes. Eye-blinks removed with Independent Component Analysis (ICA), Articulation-related artifacts reduced with Blind-Source Separation based on Canonical Correlation Analysis (BSS-CCA) as in [2]. Laplacian transformation as in [2], acting a spatial filter.

Results

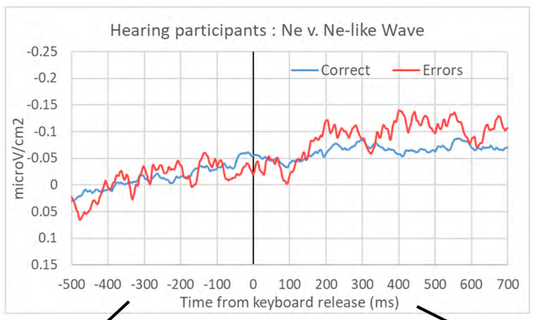
Ne/Ne-like wave in Deaf signers:

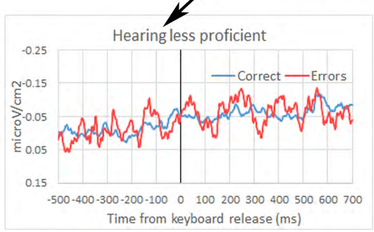


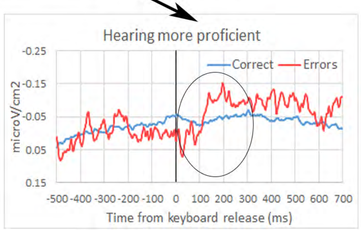


- Slope significantly different from zero between -150 ms and keyboard release (i.e. sign onset production) for both correct (p=.014) and error trials (p=.007).
- Peak-to-peak amplitude marginally greater for Ne compared to Ne-like wave (p=.057).

Ne/Ne-like wave in hearing signers - ASL proficiency effect:







- Slope not significantly different from zero between -150ms and keyboard release (i.e. sign onset production) in errors (p=.200), only in correct trials (p=.025).
- Ne slope negatively correlated with proficiency over Deaf and hearing participants (r=-.42, t=-2.13, p=.046).
- When hearing participants separated into 2 groups, emergence of a later negativity in more proficient group. Slope marginally different from zero in errors between 50 and 200 ms (p=.088), and peak-to-peak amplitude greater in errors than in correct trials (p=.038).

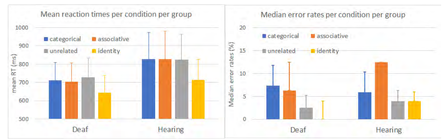
By experimental condition analysis

Initial results:

- *Hearing status*: No effect on RTs or accuracy rates.
- *Picture-word type*: Effect on RTs (Wald χ^2 (2) = 16.53, p<.001) and accuracy rates (Wald χ^2 (2) = 51.97, p<.001): identical picture-word pairs yielded faster RTs and less errors than unrelated pairs, and semantically-related pairs yielded more errors than unrelated pairs but not slower RTs.
- *Hearing status by picture-word type interaction:* No interaction on RTs but interaction on accuracy rates (Wald χ^2 (2) = 21.84, p<.001): there were more differences between conditions in the Deaf than in the hearing participants.
- *Ne-like wave:* No effect of picture-word type in Deaf participants (not enough trials in errors to conduct this analysis, and unclear Ne/Ne-like pattern in hearing group).

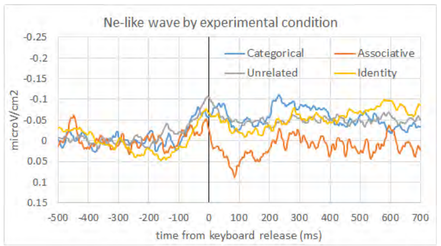
We therefore separated the initially-classified SR picture-word pairs into categorically (e.g., MOUSE-squirrel, n=34) and associatively-related pairs (e.g., KING-crown, n=16), as these pairs have been shown to cause opposite effects on RTs [3].

Post-hoc behavioral results:



- *Hearing status*: No effect on RTs, accuracy rate model did not converge.
- *Picture-word type*: Effect on RTs (Wald χ^2 (3) = 16.53, p<.001): identical picture-word pairs yielded faster RTs than unrelated pairs, associatively and categorically-related pairs did not yield slower RTs than unrelated pairs.
- *Hearing status by picture-word type interaction:* No interaction on RTs.

Post-hoc Ne-like wave results in Deaf signers:



- Marginal effect of picture-word condition on peak-to-peak amplitude of the Ne-like wave in Deaf signers (F(1,3)=2.307, p=.083).
- This is due to the associatively-related picture-word pairs, for which the Ne-like wave is marginally smaller than for the unrelated picture-word pairs (t(22)=1.89, p=.073).

Discussion points

- A similar medial frontal mechanism is engaged in pre-output language monitoring in sign and spoken language production.
- This suggests that the monitoring mechanism reflected by the Ne/Ne-like wave is independent of output modality (i.e. spoken or signed) and likely monitors pre-articulatory representations of language, in agreement with [6].
- Differences between groups may be linked to language proficiency, with more variable lexical access to motor programming latencies for hearing signers, and lower error awareness in hearing signers compared to Deaf signers [7].
- Medial frontal monitoring mechanism may be sensitive to the ease of lexical access (as defined by [3]), as indexed by the marginal facilitation effect for associatively-related compared to unrelated picture-word pairs, although these results are only preliminary.

References: [1]: Nozari et al. (2011, *Cognition*), [2]: Ries et al. (2011, *J. Cog. Neuro.*), [3]: Costa, Alario Caramazza (2005,*Psych. Bull. Rev.*), [4]: Hauser et al. (2006, American sign language - Sentence reproduction test: Development implications.), [5] Mott et al. (2017, , *SNL, Baltimore*), [6]: Ries et al. (2015, *J. Cog. Neuro.*), [7]: Nicodemus and Emmorey (2013, *Biling. Lang. Cog.*)

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