On-line measures of typing fluency reveal psycholinguistic dynamics of sentence production

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Introduction: Sentence production research in both healthy and clinical populations remains understudied relative to sentence comprehension [1,2]. In particular, the supramodal monitoring and control mechanisms employed during language production are challenging to address. Here, we introduce a novel task—the (Non-)Sentence Repetition Task (**NSRT**)—which uses a multi-phase trial design to assess supramodal syntactic competence.

Background: Within language production research, constrained sentence repetition or elicitation tasks [3,4] have revealed the Sentence Superiority Effect (**SSE**)—where a sequence of words is more accurately recalled if it is a well-formed sentence than if it is not—providing a window into subconscious syntactic processing [5]. This top-down recall strategy can result in unconscious correction of ungrammatical sentences on repetition [6]. Furthermore, typing is an underutilized modality in language production work [7]. Analysis of typed production can provide insights that spoken production cannot due to the precise incremental data produced at the segmental level both in first-pass externalization, as well as error monitoring and correction [8,9].

Methods: Trials in the NSRT occur in 3 phases: 1) presentation of a sentence to *judge* as grammatical or ungrammatical; 2) *verbatim* typed production of the presented sentence even if it was ungrammatical; and 3) reproduction of the *corrected* sentence if it was judged to be ungrammatical. The stimuli used three types of violations: determiner–noun number agreement (e.g., *one boys*), subject–verb number agreement (e.g., *two boys walks*), and tense agreement (e.g., *two boys were walk*). Each participant (N=23) saw 60 trials of which 30 were grammatical. We recorded timestamped typing data for the verbatim and correction phases. In this study, we focus on four measures of production difficulty extracted from these typing data (Fig. 1). First, we examine `onset latency` and the average delay between keystrokes, i.e., the `Interkey Interval (IKI)` as measures of advance and incremental planning respectively [10]. To focus specifically on the difficulty involved in repeating or correcting a violation, we compute the IKI over the keystrokes up to and including the violation (`CritIKI`). Finally, we operationalize (dis)fluency as the number of editing operations or backspaces up to the violation (`critEditRate`). Crucially, longer `CritIKI` suggests a preference for preventing errors whereas a higher `critEditRate` reflects a preference for post-error processing.

Results: We fit linear mixed-effects models [11] with by-participant and by-item random intercepts for onset latency and IKI analyses. Our results reveal an SSE in the verbatim trials: compared to grammatical sentences, participants were not only slower to plan ungrammatical sentences prior to onset ($\beta = 53.40, SE = 18.46, p < 0.01$), but were also slower during incremental production ($\beta = 10.74, SE = 2.68, p < 0.001$). Similarly, correction trials were characterized by longer onset latencies ($\beta = 332.25, SE = 30.38, p < 0.001$) and IKIs ($\beta = 13.867, SE = 2.692, p < 0.001$) than verbatim trials. Focusing on the production of ungrammatical sentences, we observe significant positive correlations between `onset latency` and `CritIKI` in both verbatim and correction trials (see Fig. 2). Finally, post-hoc analyses of violation types revealed that Det-N mismatch sentences had a lower `CritEditRate` than both SV and tense mismatch conditions (Fig 3). Intriguingly, however, although no difference was observed in the `CritEditRate` of SV and tense mismatch sentences, we observe a significant difference in the `CritIKI` of the two violation types.

Discussion: Our preliminary results suggest that participants delayed production in response to ungrammaticality, but may not have changed how much they planned ahead of onset since delayed onsets did not lead to a speed-up in the rate of incremental production. However, this strategy may reflect modality-specific affordances. Data collection in the spoken modality is underway and we hope to provide comparisons between strategies in the typed and spoken modalities in our presentation. Furthermore, this task offers promise in investigating the (a)symmetry of expressive and receptive syntactic deficits in people with aphasia.

Typing metrics

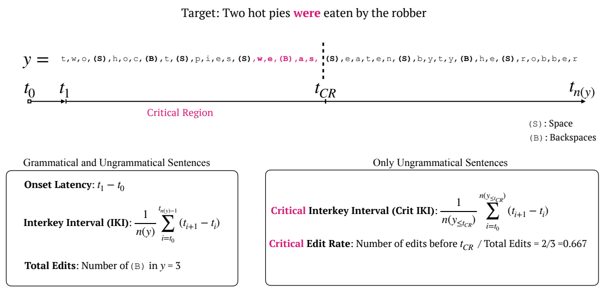

Figure 1: Measures computed from timed keystroke data collected in the verbatim and correction trials of the task

Correlation between Onset latency and CritIKI

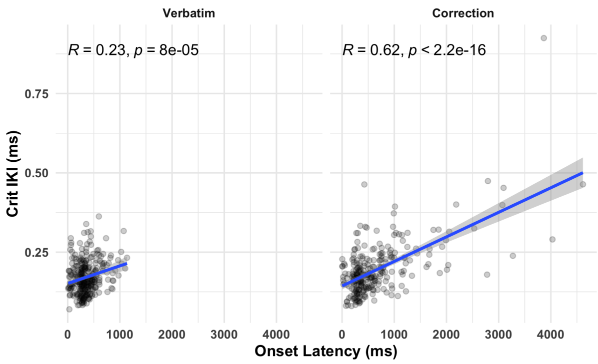

Figure 2: Correlation between `onset latency` and `IKI` in verbatim and correction trials.

Critical edit rate and IKI by violation type

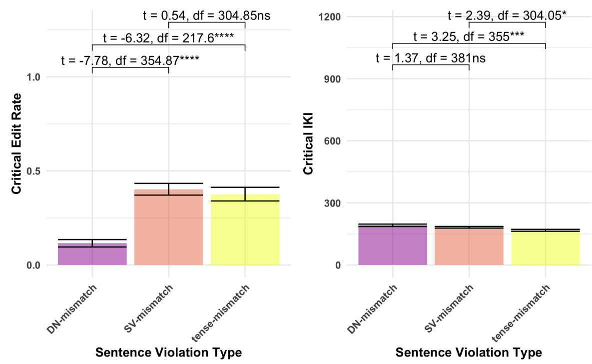

Figure 3: `CritEditRate` (proportion of edits preceding the violation) and `CritIKI` (IKI leading up to and including the violation) across the three ungrammatical violation types.

Selected References [1] Walenski et al. (2019). *Human Brain Mapping*. [2] Yeaton et al. (2024). *ms in prep*. [3] Rujas et al. (2021). *Children*. [4] Stockbridge et al. (2021). *Aphasiology*. [5] Scheerer (1981). *Psychological Research*. [6] Pinet & Nozari (2022). *Journal of Cognition*. [7] Stark et al. (2022). *Behavior Research Methods*. [8] Crump & Logan (2013). *Journal of Experimental Psychology*. [9] Pinet & Nozari (2020). *Journal of Cognitive Neuroscience*. [10] Ferreira & Swets (2002). *JML*. [11] Baayen et al. (2008) *JML*. [12] Crump & Logan (2011). *The psychology of learning and motivation* [13] Giglio et al. (2022). *Cerebral Cortex*.