Pragmatics predicts phonetic reduction in signed narratives

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Background. Theories of linguistic efficiency, such as Zipf's [1] law, claim that languages reduce effort by favoring simpler or more economical forms whenever possible. Although this claim has been tested widely in spoken languages [2], it has not been addressed as thoroughly in sign languages. However, the tendency to shorten form by a function of predictability is also observable in sign languages [3, 4]. Stamp et al. [5] analyzed reduction patterns in Israeli Sign Language (ISL), a relatively young sign language, and found that signers reduced referents that contained old information but did not do so for referents including new information. As far as we are concerned, no previous research treated referential accessibility on a graded scale (cf. [5] for binary sensitivity) and examined phonetic reduction patterns. This study uses Ariel's [6] accessibility hierarchy in Turkish Sign Language (TİD), an established sign language (believed to have been in use for more than 130 years [7]), and conducts a computer vision analysis of phonetic measures in narrative productions of deaf adult TİD signers. **Methodology.** A story-telling production experiment (retelling *Tom and Jerry* clips) was conducted with 29 signers (M_{Age} = 26 years). We adapted Ariel's [6, 8] rules of cognitive accessibility, with scores ranging from -2 (the least accessible to the addressee) to 5 (the most accessible) for each referring expression (RE) based on the distance to previous mentions, topicality, and competition between the referents. Two nominal referents, FARE 'Mouse' and KEDİ 'cat', were extracted for a computer vision analysis, resulting in 1055 unique REs. Using MediaPipe [9], an open-source library, we extracted the numerical coordinates of 33 key points on the signers' bodies in a 3D space (x, y, z). Following preprocessing (e.g., body-size normalization), we calculated three phonetic measures: (i) RE Duration; (ii) Hand Distance (Euclidean distance between the hand joint in consecutive frames), and (iii) Sign Space Use (Euclidean distance between the left and right wrists and middle-shoulder point). **Results.** Mixed-effects models were fit to analyze the phonetic measures, with Discourse (Introduction, Maintenance, Re-introduction) and Accessibility Score as fixed effects. Participant and Stimuli were the random effects. Sum contrasts were used. Discourse predicted phonetic reduction (Figure 1): REs became shorter in duration depending on the predictability of discourse context ($\beta_{\text{Introduction}} = .29 > \beta_{\text{Reintro}} > \beta_{\text{Maintenance}} = -.18$, p's < .001). The kinematic measures were reduced when the REs contained old information versus new information (*Hand*: $\beta_{\text{Introduction}} = .29$, *Space*: $\beta_{\text{Introduction}} = .06$, p's < .001) but maintenance alone did not have a significant effect compared to the grand mean (*Hand*: $p = .10$; *Space*: = $p = .40$). As accessibility increased, duration and hand distance decreased, and space became narrower (*Duration*: $\beta = -.07$; *Hand*: $\beta = -.03$; *Space*: $\beta = -.03$, all p's < .005) (Figure 2.) The polynomial order analysis also revealed three turning points ($\beta_{\text{Cubic}} = .06$, $p < .005$) for Duration and two turning points for kinematics ($\beta_{\text{Quadratic}} = .17$, $p < .04$ for *Hand*; $\beta_{\text{Quadratic}} = .17$, $p < .01$ for *Space*). **Conclusion.** The results are in line with the previous findings for spoken and sign languages [1, 3, 4] and extend them to TİD. We found that while kinematic measures were sensitive to a binary distinction between new versus old, duration was sensitive to all three discourse contexts. This might indicate that duration in older sign languages like TİD is more sensitive to nuanced distinctions in referential predictability (cf. ISL).

(a) Duration (non-kinematic) (b) Hand Distance (kinematic) (c) Signing Space Use (kinematic)

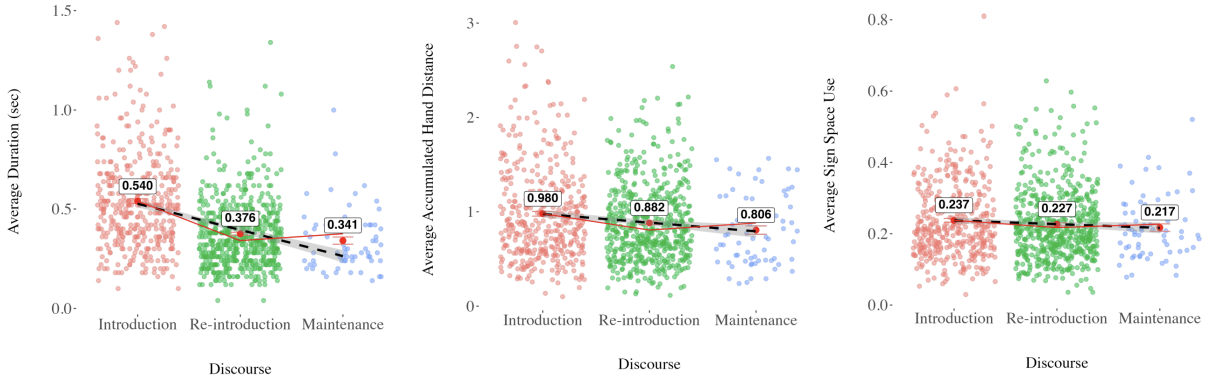

Figure 1. Average RE Duration (a), Hand Distance (b), and Signing Space Use (c) by Discourse. Each dot is a single observation (RE). The red line and points represent the mean observed value for each bin. The dashed black line is a regression line fitted across the combined data from all discourse contexts.

(a) Duration (non-kinematic) (b) Hand Distance (kinematic) (c) Signing Space Use (kinematic)

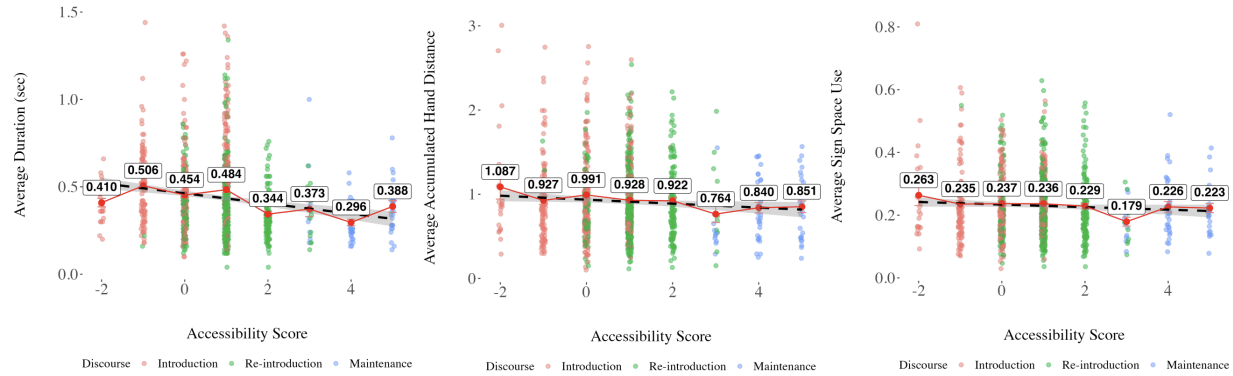

Figure 2. Average RE Duration (a), Hand Distance (b), and Signing Space Use (c) by Accessibility Score. Each dot is a single observation (RE). The red line and points represent the mean observed value for each bin. The dashed black line is a regression line fitted across the combined data from all accessibility bins.

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