Motion Capture Analysis of Verb and Adjective Types in Austrian Sign Language

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Abstract

Across a number of sign languages, temporal and spatial characteristics of dominant hand articulation are used to express semantic and grammatical features. In this study of Austrian Sign Language (*Österreichische Gebärdensprache*, or ÖGS), motion capture data of four Deaf signers is used to quantitatively characterize the kinematic parameters of sign production in verbs and adjectives. We investigate (1) the difference in production between verbs involving a natural endpoint (telic verbs; e.g. *arrive*) and verbs lacking an endpoint (atelic verbs; e.g. *analyze*), and (2) adjective signs in intensified vs. non-intensified (plain) forms. Motion capture data analysis using linear-mixed effects models (LME) indicates that both the endpoint marking in verbs, as well as marking of intensification in adjectives, are expressed by movement modulation in ÖGS. While the semantic distinction between verb types (telic/atelic) is marked by higher peak velocity and shorter duration for telic signs compared to atelic ones, the grammatical distinction (intensification) in adjectives is expressed by longer duration for intensified compared to non-intensified adjectives. The observed individual differences of signers might be interpreted as personal signing style.

Materials and methods

1. Participants

Four Deaf signers (2 F) included in the analysis (Age *M*=54, *SD* = 10, range 40-64) were born deaf or lost their hearing early in life. All of the participants who took part in the study were fluent ÖGS signers, used ÖGS as their first language in daily life, are members of the Deaf community.

2. Materials and design

The list of signs each participant produced consisted of 102 signs. The stimuli included 36 telic and 36 atelic verb signs (e.g. telic: *arrive*; atelic: *write*), 15 adjectives in non-intensified form (e.g. *sweet*), and the same 15 adjectives in intensified form (e.g. *very sweet)*. Stimuli were presented in a power point presentation, a written gloss of each sign on a separate slide. The stimuli were elicited in pseudo-randomized order, such that no sign type appeared more than two times in a row. Every other participant was presented with the list in the reversed order to eliminate potential order effects.

3. Data collection and analysis

Body kinematics of the trunk, head, and upper extremities including hands were recorded using a custom-built marker set (see Fig.1), and a 12-camera infrared motion capture system with a sampling frequency of 300 Hz. A 2D-Video (150 Hz, Qualisys AB) of the participant's frontal plane was recorded simultaneously, and time-locked to motion capture data.

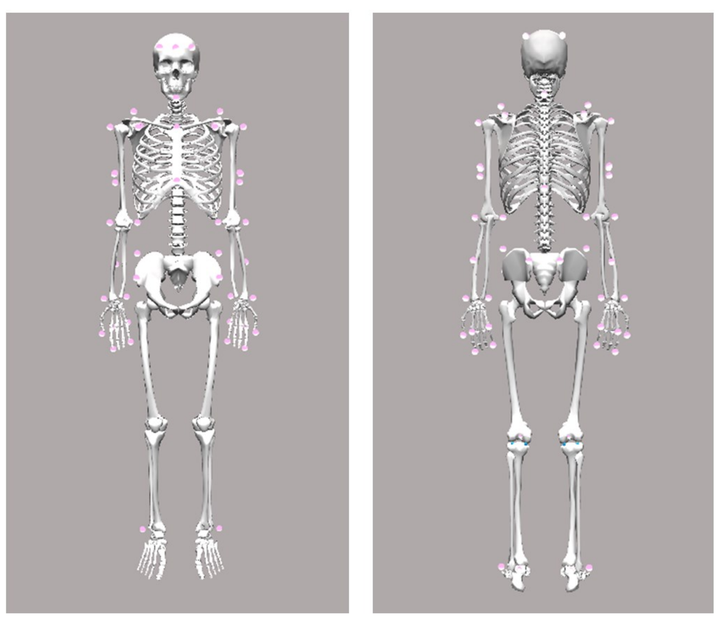

Figure 1. Marker set on skeletal representation.

Marker trajectories were low-pass filtered using a second-order, zero-lag Butterworth filter with a cutoff frequency of 25 Hz. Segment positions and orientations were determined using an inverse kinematics algorithm (V3D; C-Motion, Rockville, MD, USA). Joint centers of the wrist, elbow, and shoulder were defined as virtual landmarks at 50% of the line between the lateral and medial joint markers. The velocity of the wrist joint center (vertical component) of the dominant hand was used to define the onset (v > 0.1 m/s) and offset (v < 0.1 m/s) of hand movement. For statistical analysis, each sign was evaluated individually, and the dominant hand data for each signer and sign was used. The start and end of the sign phase was set visually by a skilled signer using 2D video recording time-aligned to motion capture data. Sign onset was defined as the video frame when the target handshape reached target location from where sign movement started (Wilbur and Malaia, 2008). Sign offset was defined as the video frame when the hand changed its shape or orientation or moved away from the final position. The complete sign was divided into 3 phases: preparation phase (hand movement onset – start sign), sign phase (start sign – end sign), and down phase (end sign – hand movement offset). Resultant absolute mean and peak velocity and acceleration of the joint centers were calculated for all three sign phases; the present analysis focused on sign phase exclusively

Results

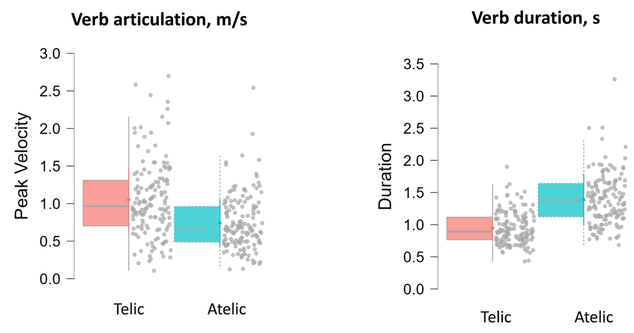

Figure 2. Verb peak velocity and duration comparison.

The effect of Verb type was examined separately for two kinematic dependent variables: (a) peak velocity and (b) verb duration (both were log transformed). The statistical analyses were conducted using linear mixed-effects (LME) models, and performed using the lme4 package in R, with Verb type (telic vs. atelic) as a fixed effect. The random effects included by-participant and by-item random intercepts. Models with random slope for Verb type in the by-participants or by-item term were also tested for convergence. Sum coding was used for main effects testing in all models. Atelic verbs were signed with a lower peak velocity, and were longer in duration compared to telic ones (cf. Fig. 2). The mixed-effects model for peak velocity revealed an effect of Verb type (Estimate: -.076; SE: .017; p < .001), as did the mixed-effects model for duration (Estimate: .101; *SE*: .023; *p* < .01).

Statistical analysis for kinematic features of adjectives was computed using LME modeling similar to the analysis for verb kinematics reported in the previous section.

Intensified adjectives were signed with a higher peak velocity compared to non-intensified adjectives, and were longer in duration (see Fig. 3). The mixed-effects model for peak velocity did not reveal an effect of Intensification (Estimate: .032; *SE*: .025; *p* = .22). The mixed effects model for duration did reveal an effect of Intensification (Estimate: .050; *SE*: .024; *p* < .05).

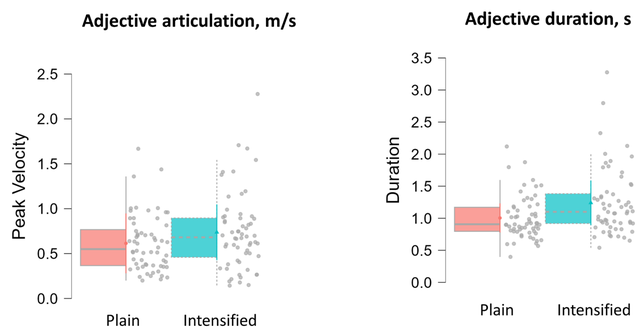

Figure 3. Adjective peak velocity and duration comparison

Variability in sign production

The data also revealed individual differences among the signers for both verbs (Fig. 4) and adjectives (Fig. 5), which might be interpreted as personal signing style (cf. Bigand et al., 2020).

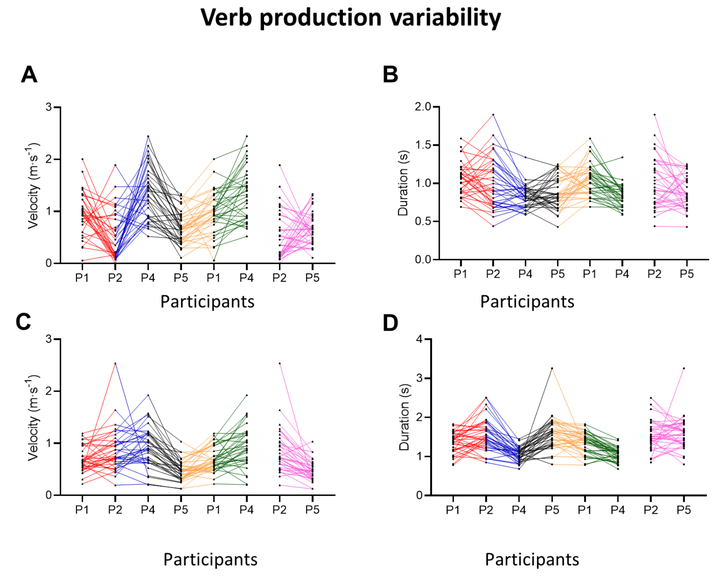

Figure 4. Pairwise comparison of 4 fluent Deaf signers (P1-P4) dominant wrist joint center velocity and duration variability within the sign phase for telic verbs (A, B) and atelic verbs (C, D).

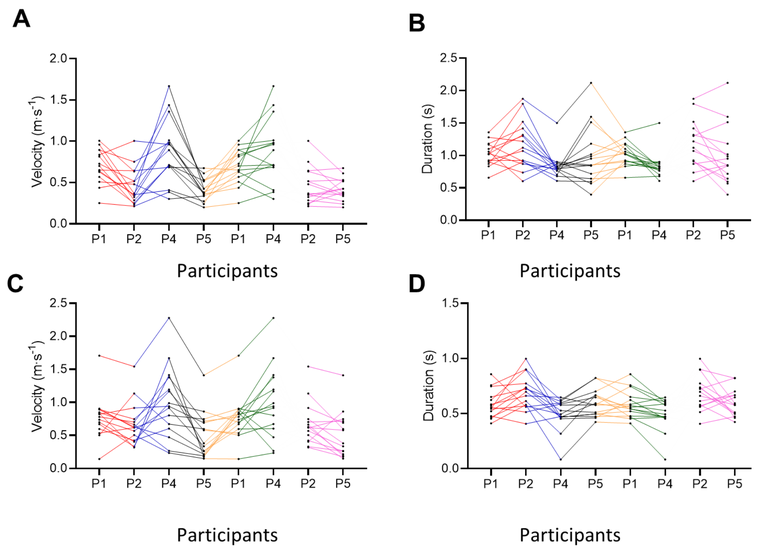

Figure 5. Pairwise comparison of 4 fluent Deaf signers (P1-P4) dominant wrist joint center velocity and duration variability within the sign phase for plain adjectives (A, B) and intensified adjectives (C, D).

Conclusions

- In ÖGS, telic verb signs were produced with a higher peak velocity and shorter in duration as compared to atelic verb signs: i.e. the linguistic difference in semantics (telic-atelic distinction) appears associated with kinematic differences in both peak velocity and duration in ÖGS.
- The longer duration in atelic verbs seems to be related to the phonological structure of the signs (i.e. most of them show a reduplicated movement component leading to a longer sign duration).
- Intensified adjectives were longer in duration compared to non-intensified adjectives.
- The duration in adjectives seems to be connected to both the span of signing space (size of the sign) and velocity of hand motion, but not to sign repetition.

Generally, in sign languages the **physical parameters of motion are recruited for semantic and grammatical markings**, but different parameters are recruited for different marking categories (cf. Wilbur 2008). The findings also point to **crosslinguistic differences**: sign languages use duration, velocity, and acceleration as grammatical markers, but weigh the salience of each physical marker differently (cf. Malaia & Wilbur 2012; Maiala et al., 2013).

References

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