Event structure reflected in muscle activation differences in Austrian Sign Language (ÖGS) verbs: First evidence from surface electromyography.

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For different sign languages, specific linguistic structures have been described as showing more tensed or accentuated articulation, or characterized by specific dynamic qualities or manner of movement (Klima & Bellugi, 1979). For Austrian Sign Language (ÖGS), such specificity has been noted for imperative sentences or intensified adjectives (e.g., *very cold*) (unpublished data). Qualitative descriptions of manner of movement are mainly based on visual inspection of 2D video material. In the present work, we used electromyographic (EMG) measurements to evaluate arm muscle activation for two verb types in ÖGS, i.e. telic verbs (involving an endpoint, such as *arrive*) and atelic verbs (lacking an endpoint, such as *analyse*). Based on 2D video analysis, Schalber (2006) noted that the two verb types differ in phonological structure. Telics show a rapid movement (deceleration) to a complete stop (EndState morpheme) which is realized in changes of the shape and orientation of the hand(s) or changes of setting (cf. Wilbur, 2008). Kinematic data analysis (motion capture) confirmed this observation and showed that telic verbs are characterized by shorter duration, higher accelerations and jerks, and higher deceleration at the end of the sign compared to atelic verbs (Krebs et al., 2021).

The telic and atelic signs (10 per category) were produced individually by a Deaf fluent signer (EMG data was collected simultaneously with kinematic data reported in Krebs et al., 2021). EMG electrodes were placed according to SENIAM (http://www.seniam.org/) guidelines at four arm muscles (m. extensor digitorum, m. flexor digitorum, m. biceps brachii and m. triceps brachii) of the dominant (right) arm and connected to a sensor unit of the EMG System (Ultium™ EMG, Noraxon). Data was collected at 2000 Hz; filtered (Butterworth low at 300 Hz, then high at 10 Hz), and smoothed (root mean square with a moving window of 151 data points (0.0755 s)). EMG mean (averaged EMG signal), EMG max (peak in EMG signal) and EMG integral (area under the EMG signal curve) were analyzed for sign phase (time interval between sign onset and sign offset) as well as hold phase (time interval after sign movement ended and the hands were held in space, i.e. before sign offset). Sign onset was defined as the video frame when the target handshape reached target location from where sign movement started (Wilbur & 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. Additionally, the phonological form of the signs was analyzed, whereby movement type (path or local) movement direction, repetition, handedness, finger flexion, contact of hands and sign location was examined. Verbs were selected based on interview data from Deaf fluent signers (conjunction

test, Borik, 2006). The telic verbs used in the study were THROW, CATCH-UP, TAKE, DISAPPEAR, CHANGE, ARRIVE, DIE, RELAX, STEAL, SUGGEST. The atelic verbs used in the study were TRAVEL, COLLECT, SHAVE, CHASE, WRITE, PAINT, SEW, EXAMINE, ANALYZE, and SWIM.

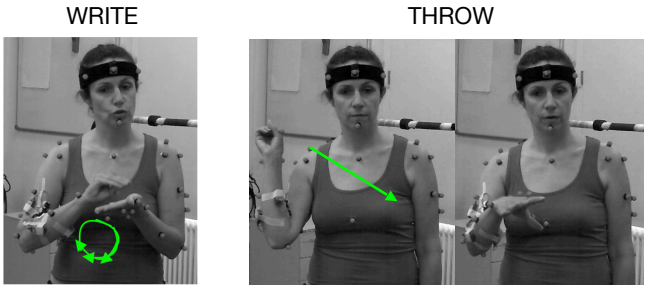

Figure 1. Examples for atelics (WRITE) and telics (THROW) in ÖGS. The atelic sign WRITE shows a repeated circular path movement; the telic sign THROW shows a single linear path movement as well as a handshape change (close -> open).

Data analysis revealed that the upper arm muscles showed significantly higher muscular activity in telic than atelic verbs: more activation was revealed in EMG max and EMG mean in the biceps in the sign phase; more activation was shown by EMG mean value in the hold phase after the sign in the triceps (see Table 1). For atelics, higher muscular activity was revealed in the forearm: higher activation was observed in the EMG integral in the extensor and flexor digitorum in the sign phase. Combining EMG results with the available kinematic data and the information about the phonological structure of the signs indicates that endpoint marking in telic signs, which is characterized by higher acceleration, jerk and deceleration at the end of a sign, is produced via higher activation in upper arm muscles in the sign and hold interval in telics as compared to atelics. It is further observed that the repeated arm/hand movement involved in the majority of the atelics (n=8), but absent in telics, requires more intense muscle activation in the forearm in the production of atelics compared to telics.

To the best of our knowledge, this is the first EMG analysis investigating muscle activation during sign language production. The presented data provide insight into the muscles involved in producing the difference in sign articulator dynamics between event types in ÖGS. EMG analysis provides new insight into how sign production is generated and helps to understand the muscle activation that affects linguistically relevant distinctions in sign languages. Research in this field not only informs about the grammar of sign languages, but also can contribute to the development of training methods and approaches for sign language learning.

Muscles (time interval)	**Upper arm muscles**			**Forearm muscles**	
	biceps - EMG max (sign phase)	biceps - EMG mean (sign phase)	triceps - EMG mean (hold phase)	extensor digitorum - EMG integral (sign phase)	flexor digitorum - EMG integral (sign phase)
atelics	33.4 (14.0)	15.7 (6.3)	2.2 (0.9)	46.6 (19.0)	20.4 (11.5)
telics	51.2 (26.3)	21.7 (7.8)	3.0 (0.4)	25.1 (7.1)	8.7 (2.7)
p-value	0.08	0.07	0.03	0.01	0.01

Table 1. Muscle activation. EMG-values in μV; standard deviations in parentheses; only significant results are reported

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