Multimodal Analysis of Sign Language Highlights Biomechanical Origins of Grammatical Markings

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Summary

Although it is known that kinematic markings are used to indicate grammatical meaning in sign languages, it is still unclear which motor control patterns influence these differences. This study found that adjective types differ in muscle activations, paving the way for further work into sign language education and research.

Introduction

While the link between grammar and motion in sign languages has long interested scientists, recent work has explored their connection using multimodal approaches. Methods like motion capture and electromyography (EMG) enable quantification of both articulatory dynamics and motor control in grammatical markers. [2] recently demonstrated for Austrian Sign Language (ÖGS) showed differences in sign duration and wrist velocity between telic verbs (with inherent endpoints) and atelic verbs (without endpoints), while intensified adjectives mainly differ in duration from non-intensified versions. This work expands on these findings by employing new motor control analytical methods to investigate sign language grammar.

Methods

This study is an extension of [1]. Six deaf signers (4F) fluent in ÖGS were prompted to produce 15 pairs of adjectives in intensified and non-intensified forms (e.g., cold - very cold). Body kinematics were recorded using motion capture (Qualisys AB, Göteborg, Sweden, 300 Hz) and wrist velocity variability was quantified with a spatiotemporal index (STI; velocity and acceleration) in MATLAB [2]. EMG (Ultium™ EMG, Noraxon, Scottsdale, AZ, USA, 2000 Hz) of the upper and lower arm was collected and normalized to the maximum voluntary contraction. A co-contraction index was calculated to approximate the degree of activation between agonist and antagonist muscles in the dominant hand (e.g., upper arm biceps and triceps) [3] using the formula of [4]. Next, the power spectral density (PSD) was obtained in five distinct frequency bands (6-15, 16-25, 26-60, 61-75, and 76-140 Hz) [5]. Finally, the relationship between wrist acceleration and upper arm EMG was quantified using cross-correlation.

Results and Discussion

STI differences were negligible between adjectives in wrist and elbow velocity ($P>0.05$) but had small differences in acceleration ($P<0.001$, $d=0.29$ and $P=0.03$, $d=0.15$, respectively). Forearm and upper arm co-contraction were higher in intensified adjective forms (Figure 1, $P=0.008$, $d=0.29$ and $P<0.001$, $d=0.39$, respectively). Most muscle groups had substantial differences in PSD between adjective pairs, despite minimal differences in average frequencies.

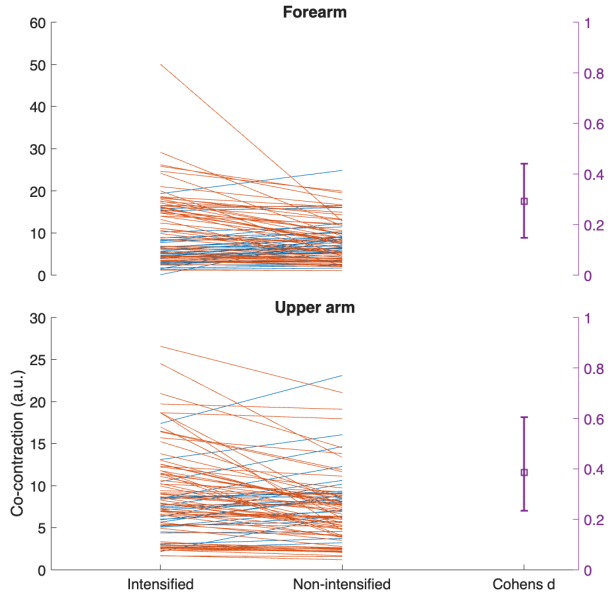

Figure 1: Gardner-Altman plots of the differences in forearm and upper arm co-contraction between intensified and non-intensified adjective pairs.

Conclusions

These findings support previous hypotheses connecting sign language articulation and production through multimodal analysis. Future work should determine if these observations match perceptions of signers and how these patterns vary with learning.

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