The Displacement-Velocity Dissociation in Sign Language Learning: Kinematic Signatures of Event Structure in Novice ÖGS Signers

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Abstract

This study investigates how adult learners acquire linguistically contrastive movement patterns in Austrian Sign Language (ÖGS), focusing on the telic/atelic distinction predicted by the Event Visibility Hypothesis. Telic verbs (bounded events) are produced by proficient Deaf signers with shorter duration and temporally precise, low-entropy velocity profiles, whereas atelic verbs (unbounded processes) show more continuous motion. Using 3D motion capture (300 Hz), we compared 8 novice learners (6–12 weeks of instruction) with 6 proficient Deaf signers across 71 verbs. Linear mixed-effects models revealed a dissociation between gross movement patterning and fine-grained velocity profile structure in learner productions. Learners correctly reproduced the proportional path-length contrast between telic and atelic verbs, replicating the gross spatial distinction of proficient signers. However, temporal marking of the telic/atelic contrast was underproduced: learners showed a significantly smaller duration difference between verb types than proficient signers, while total path length did not differ significantly between verb types or groups. Temporal control showed significant between-group differences: learners exhibited elevated sample entropy, with non-proficient velocity profiles within individual sign productions, though spatial consistency across trials (STI) was comparable to that of proficient signers. Peak velocity did not differ between groups, suggesting that learners can reach target speeds but cannot yet modulate temporal structure reliably. These findings support distinct learning trajectories for gross movement patterning and fine-grained motion complexity, and demonstrate that velocity profile structure within signs constitutes a core linguistic target in sign language learning.

Keywords: sign language learning, event structure, movement kinematics

1. Introduction

Learning any language as a second language in adulthood means mastering not only vocabulary and grammar, but also the fine-grained motor control required for the target language. For sign language learners, this motor learning challenge is particularly relevant: learners must acquire precise spatial and temporal patterns of manual articulation to convey linguistic meaning.

Recent advances in motion capture technology have made it possible to measure kinematic properties of sign production with precision. These methods showed that sign languages encode grammatical distinctions through systematic modulation of movement kinematics (Brentari, 1998; Malaia et al., 2013; Wilbur, 2003, 2008). One well-documented cross-linguistic grammatical marker is that of event structure - the distinction between telic verbs (events with inherent endpoints, such as ARRIVE or BREAK) and atelic verbs (unbounded processes, such as RUN or THINK). Proficient signers mark telic verbs with distinctive kinematics: shorter duration, reduced displacement, abrupt deceleration, and often a hold or handshape change at the endpoint (Wilbur, 2008). Atelic verbs, by contrast, are produced with more continuous movement lacking endpoint marking.

These kinematic patterns are linguistically contrastive. The Event Visibility Hypothesis (Wilbur, 2003, 2008) posits that the visual modality of sign languages permits (and favors) the systematic mapping between event structure and movement kinematics. Events with inherent endpoints are marked by abrupt changes in the movement signal, while unbounded events are expressed through reduplicated or continuous motion. This hypothesis has been supported by empirical studies across multiple sign languages, including American Sign Language (ASL), Austrian Sign Language (ÖGS), Croatian Sign Language (HZJ), and others (Krebs et al., 2025; Malaia et al., 2013; Malaia and Milković, 2021).

Little is known, however, about how learners acquire these linguistically contrastive kinematic patterns. The present study addresses these ques-

Proceedings of the 12th Workshop on the Representation and Processing of Sign Languages, pages 324–332
16 May 2026.

tions by comparing the kinematics of telic and atelic verb production in adult ÖGS learners (6–12 weeks of instruction) with those of proficient Deaf signers. Our investigation is motivated by converging evidence from spoken language acquisition suggesting that spatial and temporal aspects of articulatory control develop along different timelines. In second language (L2) speech learning, learners often achieve reasonable approximations of spatial targets (e.g., formant frequencies, place of articulation) relatively quickly, while temporal targets (e.g., voice onset time, segment duration) require extended practice and may never fully converge on native norms (Flege, 1995; Flege et al., 1999). Similarly, motor learning research has documented dissociations between spatial accuracy and temporal consistency: learners can often reach the correct spatial endpoint of a movement while exhibiting high trial-to-trial variability in timing and velocity (Schmidt et al., 2018).

Recent work by Liu et al. (Liu et al., 2025) also indicated that temporal kinematics differentiate linguistic manual movements (signs) from non-linguistic manual movements (co-speech gestures). Liu and colleagues compared ASL signers' production of classifier signs with English speakers' co-speech gestures describing the same events, and found that while spatial features (maximal area covered, trajectory shape) were similar between signers and non-signers, temporal features differed significantly. Specifically, signers' linguistic movements were temporally compressed, smoother, and more rhythmic than non-linguistic movements, while speakers' co-speech gestures were characterized by an opposite pattern (temporal stretching, increased jerkiness, and reduced rhythmicity). Liu et al. interpreted temporal compression as a hallmark of an efficient linguistic system: drawing on information-theoretic framing of language as communicative signal carrier. Liu and colleagues argue that linguistic systems (spoken or signed) develop toward signal compression to maximize information transfer efficiency, consistent with prior work demonstrating compression and structured complexity in both signed and spoken language signals (Torre et al., 2019; Andres et al., 2021; Borneman et al., 2018; Malaia and Wilbur, 2020).

The distinction between spatial and temporal control also has theoretical significance. If learners differ in spatial and temporal accuracy in sign production, this would suggest that spatial and temporal aspects of signing are governed by distinct learning mechanisms. This hypothesis aligns with dual-process models of motor learning (Fitts and Posner, 1967), which distinguish between early cognitive stages (feedback-dependent visual control of movement) and later autonomous stages (feedforward control). This distinction is also consistent with models of linguistic processing that posit partially separable visual and linguistic components operating over shared signals (Malaia and Wilbur, 2019).

The question of whether temporal aspects of signing (velocity profiles, acceleration patterns, movement smoothness) carry linguistic information at all is relatively recent in sign language research. Early models of sign languages focused almost exclusively on static parameters: handshape, location, and orientation (Stokoe, 1960; Battison, 1978). Movement, when discussed, was treated as a categorical feature (e.g., straight vs. arc, unidirectional vs. repeated) rather than as a signal with linguistically contrastive properties.

The relevance of motion in sign languages has been a topic of interest in sign language research since Klima and colleagues' (Klima and Bellugi, 1979) work demonstrating perceptual differences between signers and non-signers in processing dynamic visual stimuli, and Wilbur's (Wilbur, 2003, 2008) formulation of the Event Visibility Hypothesis. This hypothesis posits that the visual-gestural modality offers transparent mapping between event structure and the kinematic properties of manual movement. Specifically, telic events (those with inherent endpoints) are hypothesized to be marked by abrupt changes in the movement signal (holds, decelerations, handshape or orientation changes) that make the endpoint visually salient. Atelic events (unbounded processes) lack such marking and are expressed through reduplicated or more continuous movement. The linguistic nature of these kinematic distinctions is underscored by their grammatical function. Telic/atelic contrasts reflect a productive morphological distinction in sign languages (Wilbur, 2008). Additionally, signers can modulate the kinematics of a single verb stem to signal aspectual contrasts: for instance, adding repetition to a telic verb stem can derive a habitual or iterative meaning, effectively converting a bounded event into an unbounded one (Krebs et al., 2026). The kinematic marking of event structure is thus a core component of sign language grammar.

The acquisition of motor skills has long been recognized to proceed through distinct stages (Fitts and Posner, 1967). A key finding from motor learning research is that spatial and temporal aspects of motor control can develop along distinct timelines (Schmidt et al., 2018). This dissociation has been documented in a wide range of motor tasks, from reaching and grasping to handwriting and musical performance. Evidence from second language speech acquisition supports a similar dissociation in the articulatory domain. Flege et al (1999) showed that spatial targets in L2 production (e.g., vowel formant frequencies, which reflect tongue position) are often acquired earlier than temporal targets (e.g., voice onset time in stop consonants).

This dissociation persists in highly proficient late L2 learners, suggesting that temporal control is more difficult to master than spatial control.

The present study tests this hypothesis in sign language learners by measuring both spatial parameters (displacement) and temporal parameters (velocity entropy, spatiotemporal variability) in novice ÖGS learners and comparing them with proficient Deaf signers.

2. Methods

Deaf fluent ÖGS signers (N=6) and hearing learners with initial ÖGS exposure (N=8; 6-12 weeks of weekly instruction for 1.5 hours) participated in the study. Deaf participants were either born Deaf or became Deaf early in life, used ÖGS as their primary language in daily life, and identified as members of the Deaf community. Five self-reported as right-handed; one as left-handed. All learners were hearing adults; none had prior exposure to sign language before beginning instruction. All participants gave informed consent in accordance with institutional review board protocols.

The stimuli consisted of 71 ÖGS verb signs (35 telic, 36 atelic) selected from the proficient signer corpus (Krebs et al., 2025). Telic verbs denote events with inherent endpoints (e.g., ARRIVE, ADMIT, OPEN), while atelic verbs denote unbounded processes (e.g., RUN, DANCE, WALK). Verb selection was based on the Event Visibility Hypothesis (Wilbur, 2003, 2008), which predicts that telic verbs are kinematically marked with abrupt endings (sharp deceleration, holds, handshape/orientation changes), whereas atelic verbs lack such marking and are produced with smooth, continuous movement.

For learner participants, stimuli were presented as video recordings of a proficient Deaf signer producing each verb sign. Deaf signer participants, being fluent users of ÖGS, produced each verb sign from their established lexicon without video prompting, following the protocol described in (Krebs et al., 2025); sign boundaries for all participants were determined using the annotation procedure as detailed in methods of the same work. Each video was presented once (though participants could rewatch the video if they wanted), and learners were instructed to reproduce the sign as accurately as possible.

Body kinematics (torso, head, and arms/hands) were recorded using a marker set and a 12-camera infrared motion capture system (Qualisys AB, Göteborg, Sweden) operating at 300 Hz. Simultaneously, a 2D video of the participant was recorded and time-synchronized with the motion capture data. Infrared-reflective markers (diameter 12 mm) were placed on anatomical landmarks following standard protocol (Krebs et al., 2025). Key markers included bilateral placement on shoulders, elbows, wrists, and hands.

Marker trajectories were exported from Qualisys Track Manager and processed in MATLAB (MathWorks). Raw 3D coordinate data were low-pass filtered using a second-order zero-lag Butterworth filter with a cutoff frequency of 25 Hz to remove high-frequency noise while preserving biologically relevant movement frequencies. Segment positions and orientations were calculated using an inverse kinematics algorithm (Visual3D; C-Motion, Rockville, MD).

All participants began each sign from the same resting position with arms at the sides of the body. Sign onset and offset were visually determined by a skilled signer using the time-aligned 2D video recording. Sign onset was defined as the video frame when the hands reached the target location from which the sign movement started. Sign offset was defined as the frame when handshape or hand orientation changed or when the hands moved away from the final position. The dominant hand was operationalized as the hand used for producing one-handed signs. All kinematic analyses were conducted on the dominant hand wrist marker trajectory.

Ten kinematic parameters were extracted from the wrist trajectory of each sign token:

Spatiotemporal parameters: (1) Sign duration (seconds), measured from sign onset to offset and (2) total path length (meters) of the wrist, calculated as cumulative Euclidean distance traveled by the wrist marker across successive time points over the course of the sign:

$$L = \sum_{i=1}^{N-1} \sqrt{(x_{i+1} - x_i)^2 + (y_{i+1} - y_i)^2 + (z_{i+1} - z_i)^2}$$

Because path length is derived from the same position time series as velocity, it reflects the cumulative magnitude of movement and is sensitive to both overall length of path traveled, and within-trajectory variability, but does not encode temporal structure (Wilbur and Malaia, 2008). **Kinematic parameters**: (3) Median velocity (m/s) and (4) peak velocity (m/s), computed from the first derivative of position. (5) Peak deceleration (m/s^2), extracted from the second derivative (acceleration profile) as the maximum negative value. (6) Jerk (m/s^3), calculated as the third derivative of position, reflecting smoothness of movement.

Complexity parameters: (7) Sample entropy, calculated from the wrist speed vector using embedded dimension m = 2 and tolerance r = 0.2 × standard deviation (Richman and Moorman, 2000). Higher values of sample entropy indicate more irregular, less predictable movement patterns. (8)

Spatiotemporal index (STI) for velocity and (9) STI for acceleration, computed as the sum of standard deviations across 50 time-normalized points (Howell et al., 2009). STI measures trial-to-trial variability in movement patterning. (10) Movement rhythmicity, quantified as the standard deviation of interpeak intervals in the velocity profile.

Sample entropy and STI serve as complementary measures of movement complexity. Sample entropy captures the informational complexity within a single movement trajectory (intra-trial regularity), while STI quantifies consistency across repeated productions of the same sign (inter-trial variability). Following Malaia and colleagues (2012, 2016, 2018), we interpret sample entropy as a proxy for fractal complexity: the degree to which a movement contains information at multiple temporal scales. In the context of linguistic signing, higher entropy reflects movements that are informationally rich and potentially carry linguistic contrast; lower entropy reflects movements that are more stereotyped and predictable. Linear mixed-effects models (LME) were fit to each kinematic parameter using the lme function in MATLAB. Fixed effects included Group (Deaf signers vs. learners), Verb Type (telic vs. atelic), and their interaction. Random effects included intercepts for Participant and Verb Item, plus by-participant random slopes for Verb Type. Models were fit using restricted maximum likelihood (REML). Effect sizes were reported as partial eta-squared (η^2). Statistical significance was assessed at α = .05. We present descriptive statistics alongside LME estimates for ease of comparison; however, all inferential statistics are based on the LMM results, which account for nested data structure and unbalanced designs.

3. Results

The kinematic analysis revealed a statistically significant dissociation between spatial and temporal aspects of sign production in learners as compared to proficient Deaf signers. Even though both groups showed similar spatial patterns in sign production (as indicated by displacement differences between telic and atelic verbs), they differed in temporal control. Table 1 presents summary statistics and LME results for key kinematic parameters.

3.1. Gross Movement: Preserved Telic/Atelic Distinction

Both groups showed significant main effects of Verb Type on sign duration ($\beta = -0.42$, SE = 0.03, $p < .001$, $\eta^2 = .17$). The Group × Verb Type interaction for sign duration was also significant ($\beta = 0.13, SE = 0.04, p < .001, \eta^2 = .01$). Learners produced a smaller temporal contrast between telic and atelic verbs than proficient signers did, suggesting an emerging, but not yet fully automated temporal marking of telicity. Total path of dominant hand movement within the sign (Euclidean distance) did not differ significantly between verb types ($\beta = -0.07$ $p > .05$) or between groups ($\beta = -0.06$ $p > .05$). This null result indicates that learners were not, at this point in their learning, tracking the fine-grained differences in trajectory between telic and atelic verb signs: the contrast they preserved was one of overall sign timing.

3.2. Temporal Control: Motion Entropy in Learners

Proficient signers demonstrated low entropy for telic verbs (0.03 $\pm$ 0.04) and somewhat higher entropy for atelic verbs (0.13 $\pm$ 0.15), yielding a large main effect of Verb Type ($\beta = -0.11$, SE = 0.02, $p < .001$, $\eta^2 = .20$) on the sample entropy measure. This pattern reflects the smooth, rapid articulation of telic signs contrasted with the more variable production of atelic signs.

Learner productions showed higher entropy across both verb types. While learners' telic sign entropy (0.04 $\pm$ 0.04) was similar to that of proficient signers, learners' atelic verb entropy (0.19 $\pm$ 0.14) was substantially higher than that of proficient signers. The Group $\times$ Verb Type interaction was significant ($\beta = -0.03$, SE = 0.01, $p < .001$, $\eta^2 = .01$), indicating that learners produced telic and atelic signs with a larger difference in entropy than proficient signers.

Interestingly, the STI velocity results showed no significant group differences (Deaf telic: 0.0048 $\pm$ 0.0030; Deaf atelic: 0.0056 $\pm$ 0.0051; Learner telic: 0.0053 $\pm$ 0.0029; Learner atelic: 0.0072 $\pm$ 0.0059; Group effect: p = .48, $\eta^2 = .00$). This suggests that trial-to-trial spatial consistency was comparable between groups, in that learners could reproduce similar spatial trajectories across repetitions of the same sign. The temporal control deficit captured by elevated sample entropy in learners, then, reflects within-trial irregularity (how smoothly velocity unfolds during a single sign) rather than across-trial inconsistency (how variable the spatial path is from one production to the next). This dissociation between within-trial temporal structure and across-trial spatial consistency further supports the interpretation that learners have acquired spatial targets but not yet automatized smooth temporal control.

Velocity parameters (median velocity, peak velocity) showed weak or non-significant effects, with the exception of a small Verb Type effect for peak velocity ($\beta \approx 0$, $p = .02$, $\eta^2 = .01$). Importantly, there was no Group difference in peak velocity ($p = .82$), suggesting that although learners could achieve similar maximum speeds as proficient signers, they were not yet able to modulate velocity profiles consistently.

4. Discussion

The present study demonstrates a dissociation between gross and fine aspects of motor control in beginning sign language learners. After just 6–12 weeks of ÖGS instruction, learners successfully reproduced the relative gross distinctions between telic and atelic verbs: they produced telic signs as shorter in duration and more spatially compact than atelic signs, replicating the pattern of proficient Deaf signers. However, learners' temporal control was only emerging, as characterized by higher sample entropy (irregularity within individual sign productions), although their spatial consistency across trials, as measured by STI, was comparable to that of proficient signers. This finding has implications for theories of motor learning and sign language acquisition.

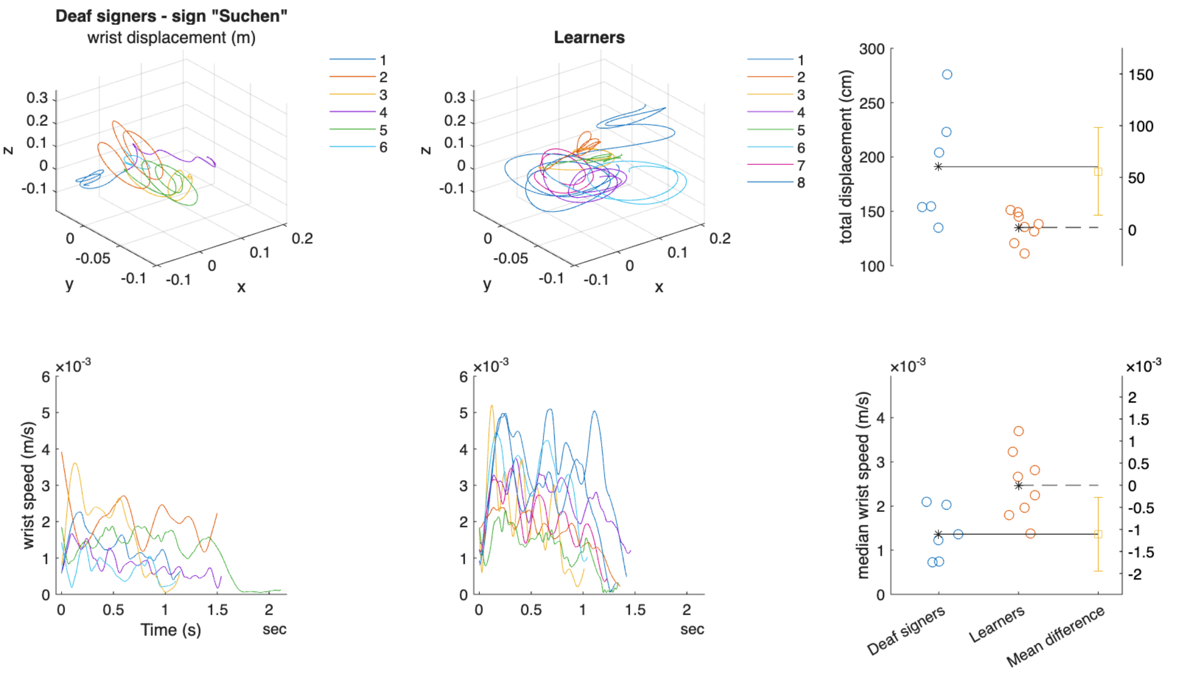
4.1. Gross Movement Patterns Acquired Before Fine-Grained Information Structure in Movement Complexity

The observed dissociation between preserved path-length contrasts in production of telic and atelic verb signs, and disordered velocity profile structure in learners suggests that gross and fine-grained kinematic features are acquired on different timelines. After 6–12 weeks of ÖGS instruction, learners successfully reproduced the gross kinematic markers of the telic/atelic distinction: they produced telic signs as more spatially compact than atelic signs, with a proportional path-length difference matching that of proficient signers. By contrast, the fine-grained velocity profile structure showed significant between-group differences: learners' production was characterized by higher sample entropy overall, as well as an exaggerated entropy difference between verb types. Why might gross movement patterning be acquired before fine-grained motion complexity? The answer may lie in what is perceptually accessible to a learner observing a model signer. Gross properties of motion profile — e.g. observation that telic signs cover less space and stop more abruptly than atelic signs — are directly visible and imitable through visual monitoring of movement. Fine-grained properties, like the shape of the velocity curve, the degree of smoothness across the deceleration phase, and the modulation of movement complexity, are not directly readable from visual observation at early stages of learning. Recent work by Karabüklü et al. (Karabüklü et al., 2025) showed that sign language learners increase visual temporal resolution through the first two years of instruction, reaching maximal temporal resolution only after 12–18 months. The present analysis characterizes an early stage of language learning, where gross movement targets have been approximated (perhaps through visual self-monitoring), but fine-grained structure of motion, which depends on both perceptual sensitivity and motor automatization — remains to be learned. This account is consistent with dual-process models of motor learning (Fitts and Posner, 1967), which distinguish early cogni-

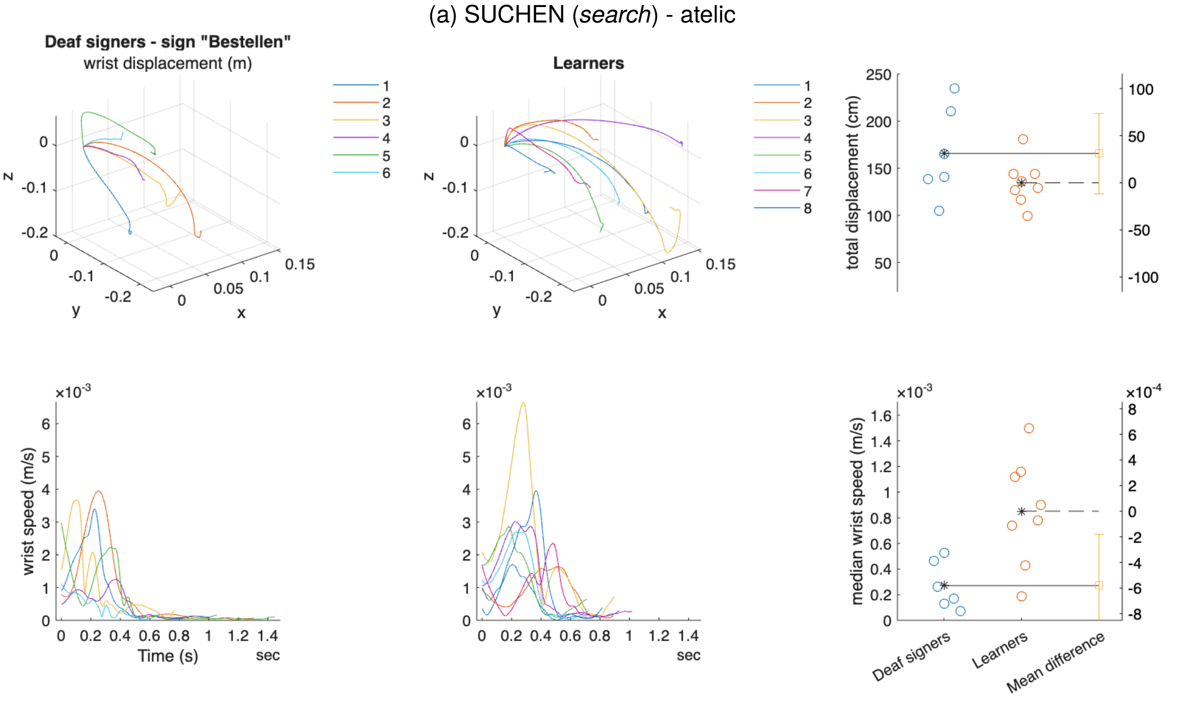
Table 1: Summary statistics and linear mixed-effects model results for key kinematic parameters.

Parameter	Deaf Telic	Deaf Atelic	Learner Telic	Learner Atelic	Group β (η^2)	Verb Type β (η^2)
Sign duration (s)	0.91 ± 0.45	1.35 ± 0.65	0.90 ± 0.31	1.19 ± 0.38	-0.16*** (.03)	-0.42*** (.17)
Total path length(m)	0.27± 0.17	0.37± 0.35	0.35 ± 0.19	0.47 ± 0.35	0.06 (.00)	-0.07 (.00)
Median velocity (m/s)	0.00038 ± 0.00054	0.00092 ± 0.00073	0.00088 ± 0.00089	0.00130 ± 0.00092	~0*** (.04)	~0*** (.05)
Peak velocity (m/s)	0.0032 ± 0.0019	0.0022 ± 0.0013	0.0037 ± 0.0021	0.0027 ± 0.0015	n.s. (.00)	~0* (.01)
Sample entropy (wrist speed)	0.03 ± 0.04	0.13 ± 0.15	0.04 ± 0.04	0.19 ± 0.14	0.04*** (.03)	-0.11*** (.20)
STI (wrist velocity)	0.0048 ± 0.0030	0.0056 ± 0.0051	0.0053 ± 0.0029	0.0072 ± 0.0059	n.s. (.00)	n.s. (.00)
STI (wrist acceleration)	0.00039 ± 0.00029	0.00058 ± 0.00052	0.00044 ± 0.00030	0.00078 ± 0.00057	n.s. (.00)	n.s. (.00)
Peak deceleration (m/s^2)	-0.0001 ± 0.00009	-0.00007 ± 0.00005	-0.0001 ± 0.00008	-0.00009 ± 0.00007	n.s. (.00)	~0* (.01)

Note. Descriptive statistics are median ± IQR. LME estimates (β) are shown with partial η^2 in parentheses. ***p < .001, *p < .05, n.s. = not significant. Interaction effects were significant for sign duration (β = 0.13, p < .001, η^2 = .01) and sample entropy (β = -0.03, p < .001, η^2 = .01).



(a) SUCHEN (*search*) - atelic



(b) BESTELLEN (*order*) - telic

Figure 1: Example wrist trajectories for Deaf signers (left) vs. learners (middle) across 2 ÖGS verbs (SUCHEN, BESTELLEN). Each colored line is one repetition. Note high spatial convergence but velocity variability in learner productions (right). Error bands show within-group variability.

tive stages, characterized by feedback-dependent control of salient movement properties, from later autonomous stages, characterized by feedforward control of motion kinematics. It also aligns with evidence from second language speech acquisition, where globally perceivable articulatory targets (vowel formant frequencies, place of articulation) are acquired earlier than fine-grained temporal targets (voice onset time, segment duration) that require extended perceptual-motor practice (Flege, 1995; Bradlow et al., 1997). Our results extend this principle to sign language learning, where we show that gross movement patterning (where to move and how fast) is acquired early, while fine-grained motion complexity (how to modulate velocity profile structure to carry linguistic information) requires extended experience. The STI results point to an important additional constraint on this interpretation. Trial-to-trial spatial consistency, as measured by STI for both velocity and acceleration, did not differ between groups (both $p > .12$). This confirms that learners' fine-grained deficit is not one of gross motor inconsistency: they can reproduce similar movement paths across repeated productions of the same sign. The between-group difference in sample entropy then reflects within-trial irregularity — the smoothness and structure of the velocity profile during a single sign production — rather than cross-trial variability in where the hand goes, characterized by STI. Learners produce spatially consistent but temporally unstructured sign kinematics: the pattern predicted by a model in which gross movement targets precede fine-grained motion complexity in acquisition.

4.2. Motion Complexity as Linguistic Target

Proficient signers produce telic verbs with very low entropy (0.03 ± 0.04), reflecting smooth, highly predictable movement. This is not a byproduct of making the movement shorter or faster; it is a specific kinematic signature that marks telicity in ÖGS and in other sign languages (Malaia et al., 2013). Learners produce signs that are accurate in terms of gross movement patterning — correctly reproducing the relative spatial compactness of telic signs — but not in terms of motion complexity. These productions can be thought of as phonetically accented: having the right gross shape but lacking the internal kinematic structure of native signing.

Interestingly, learners are not producing signs with insufficient entropy; they are overproducing in terms of complexity. Learners' atelic signs show entropy values (0.19 ± 0.14) significantly higher than those of proficient signers (0.13 ± 0.15); learners' telic signs, while lower in sample entropy than atelic ones, still exceed proficient norm. Malaia and colleagues have argued that motion complexity (as quantified via sample entropy or power spectral density) reflects information-carrying capacity of the signal (Malaia et al., 2018; Borneman et al., 2018) and is consistent with evidence that temporally structured visual linguistic input engages predictive neural mechanisms that are refined through experience (Malaia et al., 2026). For linguistic signals to be efficiently processed, information must be distributed across these scales: too little entropy yields a signal that is overly predictable and carries minimal information; too much entropy yields a signal that is excessively noisy and inefficient to produce. Recent work linking spatiotemporal neural coherence to predictive inference in sign language perception supports the role of temporally structured motion signals in efficient communication (Borneman et al., 2025).

Proficient signers operate within this optimal zone for motion complexity, with telic verbs showing low entropy (high predictability) and atelic verbs showing moderate entropy (informational richness without excessive noise). Learners, in contrast, have not yet calibrated the upper bound of complexity in production: their atelic signs' parameters exceed the proficient complexity range, while their telic productions are already close to proficient norms.

Borneman et al. (Borneman et al., 2018) demonstrated that proficient ASL signing shows higher fractal complexity than non-linguistic motion precisely because linguistic motion is both informationally rich and temporally structured. Learners' elevated entropy, paradoxically, reflects less linguistic structure, not more: they have not yet acquired the temporal scaffolding that permits efficient information transfer. This interpretation is consistent with the Event Visibility Hypothesis (Wilbur, 2003, 2008), which posits that telic verbs are marked by rapid, visually salient changes that reliably signal boundedness. The low entropy of telic verbs in proficient signers reflects not a reduction in information, but rather the concentration of information into discrete, identifiable events. Learning to sign is thus not merely learning where to move (spatial targets) but how to move (temporal structure), and, more specifically, how to modulate movement complexity to create visual signals that map to grammatical markers of sign language.

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