What sign languages tell us about phonetics:

Expanding the notion of articulatory effort

Nathan Sanders

Haverford College

work done in collaboration with
Donna Jo Napoli from Swarthmore College

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Nathan Sanders
Haverford College

Donna Jo Napoli
Swarthmore College

Roadmap of the talk

1. Articulatory effort
2. Sign language phonetics
3. Active versus reactive effort
4. Summary

Articulatory effort

Background

There is more than a century of functional work recognizing the role of articulatory effort in (spoken) language:

Passy 1891, Jespersen 1894, Martinet 1952, 1955, Kiparsky 1968, King 1969, Lindblom and Maddieson 1988, Lindblom 1990, Vennemann 1993, Willerman 1994, Flemming 1995, Boersma 1998, Hayes 1999, etc.

Defining articulatory effort

Kirchner 1998, 2004: Sum of all articulatory forces involved throughout the duration of the articulation, both those which result in movement and those which isometrically hold an articulator in place.

$$\text{total articulatory effort} = \int_{t_i}^{t_j} |\mathbf{F}(t)|\, \mathrm{d}t$$

Strategies for effort reduction

As humans become more proficient in a physical activity, including using language, we find ways to perform that activity more efficiently, by reducing articulatory effort:

- reduce number of moving articulators
- reduce distance moved
- reduce mass moved
- reduce isometric (stabilizing) forces
- and probably others

Effort reduction in spoken languages

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- **reduce isometric (stabilizing) forces:** Kirchner's explanation for why lenition results in non-strident, rather than strident, continuants

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- **reduce isometric (stabilizing) forces:** stay tuned!

Sign language phonetics

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"Sign language phonetics"!

- ~~*phonetics* < Greek *φωνή (phōnē)* 'sound'~~
- ~~*language* < Latin *lingua* 'tongue'~~
- but despite etymology, *language* refers to any language, regardless of its modality (i.e. both sign and spoken)
- similarly, despite etymology, *phonetics* refers to (the study of) the physical properties of any language, regardless of its modality

Sign language articulators

manual: arms, hands, fingers, thumbs

nonmanual: eyebrows, nostrils, lips, tongue, head, torso

Manual movement

path movement: movement at the shoulder or elbow (e.g. ASL STAY and SAME)

local movement: movement at the radioulnar, wrist, base, or interphalangeal (e.g. ASL YES and YELLOW)

Active versus reactive effort

Definition of active effort

Active effort: The effort used to move or stabilize an articulator itself. This is the usual understanding of articulatory effort. For manual movement in a sign language, this would be the effort needed to move the manual articulator, by engaging the biceps, triceps, etc.

Definition of reactive effort

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For manual movement in a sign language, this is the effort needed to prevent the manual articulators from destabilizing (twisting or rocking) the torso, which we resist by engaging the abdominals, back muscles, obliques, etc.

Definition of reactive effort

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We seem to be the first researchers to look at reactive effort!

Avoidance of torso movement

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- bipedal locomotion induces twisting, which is destabilizing, but the human muscles evolved differently from other great apes to resist this twisting (the other great apes rock side to side to stabilize themselves) (Lovejoy 1988)
- humans use eye gaze for nonverbal communication, and a fixed torso position helps (Kobayashi and Kohshima 2001)

Avoidance of torso movement

An upright, forward-facing torso orientation is also specifically preferred in signing, because torso movement often carries a linguistic function, such as surprise (Sze 2008), marking topic boundaries (Winston and Monikowski 2003), role shifting (Engberg-Pedersen 1993), etc. So extraneous torso movement could be misinterpreted by the addressee as meaningful.

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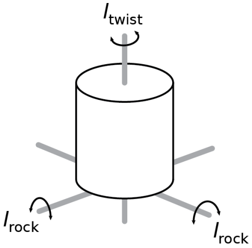
Thus, torso stability is a crucial concern for humans in general, but especially within the context of sign language communication.

Avoidance of torso movement

All objects have a natural inherent resistance to being moved: mass (*m*) resists linear movement, and moment of inertia (*I*) resists rotation. Approximating the torso as a cylinder, we have two main relevant moments of inertia:



Avoidance of torso movement

The formulas for these two moments of inertia are:

$$I_{\text{twist}} = \frac{mr^2}{2} \qquad I_{\text{rock}} = \frac{m(3r^2 + 4h^2)}{12}$$

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This inequality means that twisting is more easily induced than rocking, because the torso has less inherent resistance to twisting, requiring us to expend more reactive effort to resist it.

Predictions

Since articulatory ease is a factor in synchronic casual variation, which can lead to diachronic change, we predict to see some bias in the lexicon, such that:

- **destabilizing** signs (those which induce either twisting or rocking), should be **less common** than stable signs (which induce no torso movement)

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- **destabilizing** signs (those which induce either twisting or rocking), should be **less common** than stable signs (which induce no torso movement)
- signs that induce **twisting** (which has a lower moment of inertia and thus, less inherent resistance to offer) should be **less common** than signs that induce rocking

Our reactive effort studies

We tested these predictions in Sanders and Napoli 2016a and Sanders and Napoli 2016b.

Our reactive effort studies

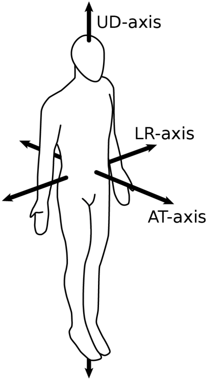
We compiled signs with **free, single or retraced two-handed path movement.**

Original study: Italian Sign Language (LIS; Romeo 1991), Sri Lankan Sign Language (SLSL; Sri Lanka Central Federation of the Deaf 2007), and Al-Sayyid Bedouin Sign Language (ASBSL; Meir et al. 2012).

Follow-up study: 24 languages from the online database Spreadthesign (2014).

Our reactive effort studies

We coded those signs for six types of movement, along three cardinal axes (away-toward (AT), up-down (UD), left-right (LR)) and three relative directions between the hands (+ for the same direction, – for the opposite direction, and 0 for no movement).



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For example, ACTIVITY in ASL would be coded as $+$LR, since the hands move in the same direction along the LR-axis, while ALLIGATOR in ASL would be coded as $-$UD because the hands move in opposite directions along the UD-axis.

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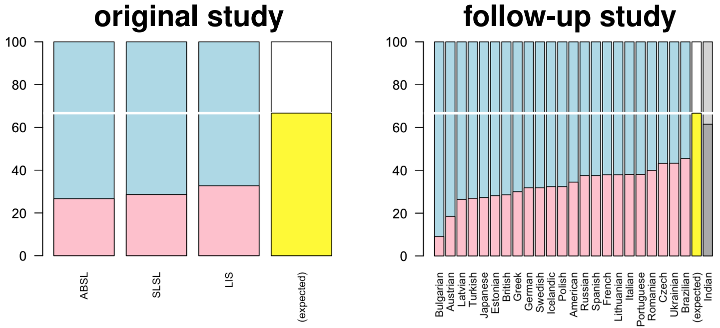
Signs can be multiaxial. For example, PACK in ASL would be coded as 0AT $-$UD $+$LR.

Our reactive effort studies

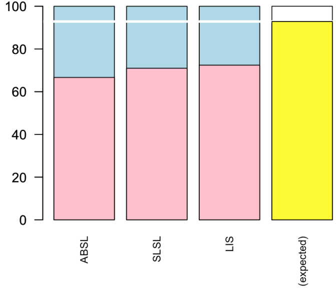
Monoaxial signs: four destabilizing movements (+AT, −AT, −UD, −LR) and two stable movements (+UD, −LR)



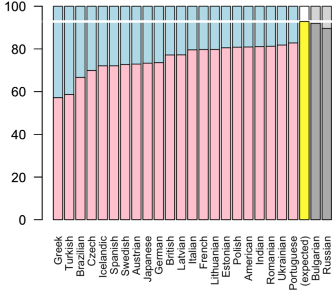
Our reactive effort studies

Multiaxial signs: thirteen destabilizing movements and one stable movement (we ignore cognitively difficult movements with AT and UD having opposite signs)

original study



follow-up study



Our reactive effort studies

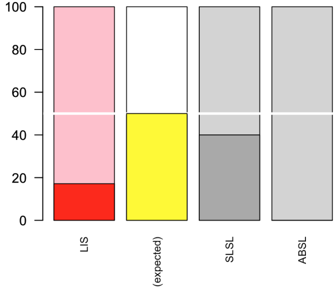
We find that for both monoaxial and multiaxial signs, in all languages, destabilizing signs are less common than would be expected by chance frequency (nearly all comparisons, 51 out of 54, are statistically significant). First prediction fulfilled!

Furthermore, in both cases, the languages are almost all statistically indistinguishable from each other (except Greek and Turkish in the multiaxial comparison), which points to a **cross-linguistic universal**.

Our reactive effort studies

Destabilizing monoaxial signs: two twisting movements ($-$AT and $+$LR) and two rocking movements ($+$AT and $-$UD)

original study



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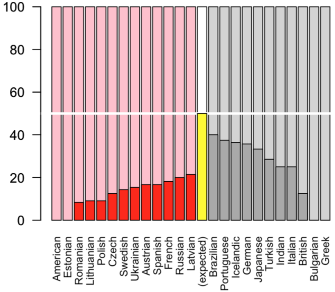

Our reactive effort studies

We find that for destabilizing monoaxial signs, in all languages, twisting signs are less common than would be expected by chance frequency (about half of the comparisons, 14 out of 27, are statistically significant). Second prediction fulfilled!

Here, the languages are all statistically indistinguishable from each other, which even more strongly points to a **cross-linguistic universal**.

Summary

Results of our studies

Reactive effort is a previously unstudied facet of articulatory effort that needs to be distinguished from active effort and is easier to study in sign languages. It is reduced in various ways in the lexicons of more than two dozen languages, following essentially the same mathematical pattern across languages (which suggests a cross-linguistic universal).

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- among both monoaxial and multiaxial signs, destabilizing movements are less common than would be expected by random chance; predicted by reduction of reactive effort needed to keep torso stable
- among monoaxial signs, twisting movements are less common than rocking movements than would be expected by random chance; predicted by greater moment of inertia of rocking versus twisting, aiding reduction of reactive effort needed to keep torso stable

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Thank you!

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