# Active and reactive effort in sign language phonetics

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# Roadmap of the talk

1. Articulatory effort
2. Sign language phonetics
3. Active effort
4. Reactive effort
5. Summary

# Articulatory effort

# Background

Long tradition of functional work recognizing the importance of reducing 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

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

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- **reduce distance moved:** e.g. place assimilation
- **reduce mass moved:** e.g. shift of palatals to coronals
- **reduce isometric (stabilizing) forces:** Kirchner's explanation for why lenition results in non-strident, rather than strident, continuants

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- **reduce distance moved:** e.g. location undershoot (ASL KNOW is sometimes articulated under the eye)
- **reduce mass moved:** stay tuned!
- **reduce isometric (stabilizing) forces:** stay tuned!

# Sign language phonetics

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- ~~*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

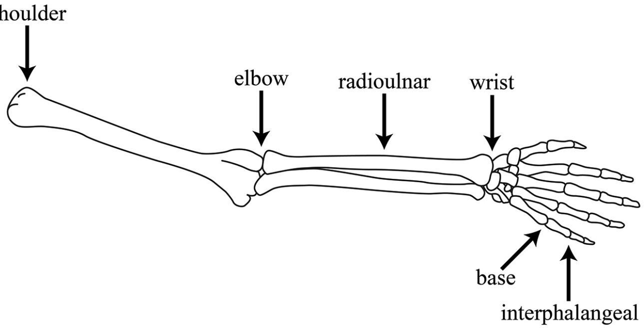
**manual**

arms, hands, fingers, thumbs

**nonmanual**

eyebrows, nostrils, lips, tongue, head, torso

# Manual joints



# Manual movement

**path**

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

**local**

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

# Active 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.

# Joint proximity and active effort

| | | | | | |
|---|---|---|---|---|---|
| shoulder | elbow | radioulnar | wrist | base | interphalangeal |
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The more proximal a joint is (i.e. the closer to the torso), the more mass it moves. Therefore, distance from the torso inversely correlates to active effort.

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In Napoli et al. 2014, we tested these predictions.

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- recruited two native ASL signers in their 30s, one male (from Austin TX) and one female (from Philadelphia), asked to sign the list as if in casual conversation
- coded signs for movement of the six joints, both for citation form and for each speaker's casual version(s)

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First prediction fulfilled! Freezing preferred to grafting.

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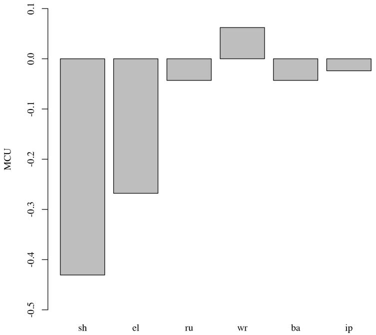
We also found that the mean change in usage (MCU) of a joint corresponded to its proximity (with a caveat):



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# 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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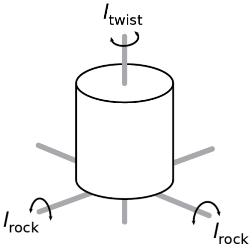
Thus, torso stability is a crucial concern for humans in general and especially within the context of signing.

# Avoidance of torso movement

Rotational inertia is how much an object resists being rotated (roughly speaking, the rotational equivalent of mass). Approximating the torso as a cylinder, we have:



# Avoidance of torso movement

The formulas for these two moments of inertia are:

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This means that twisting is more easily induced than rocking, because the torso offers 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 bias in the lexicon, such that:

- **stable** signs (which induce no torso movement) should be more common than by chance frequency, and thus, **destabilizing** signs (those which induce either twisting or rocking), should be less common

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- **stable** signs (which induce no torso movement) should be more common than by chance frequency, and thus, **destabilizing** signs (those which induce either twisting or rocking), should be less common
- signs that induce rocking (which has a higher moment of inertia) should be more common than signs that induce twisting

## Our second study: Design

- compiled signs with **free, single or retraced two-handed path movement** for 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)

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- coded those signs for six types of movement, along three cardinal axes (away-toward, left-right, up-down) and two relative directions between the hands (the same or opposite direction)

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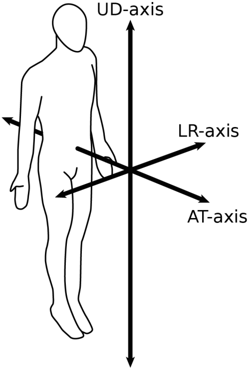

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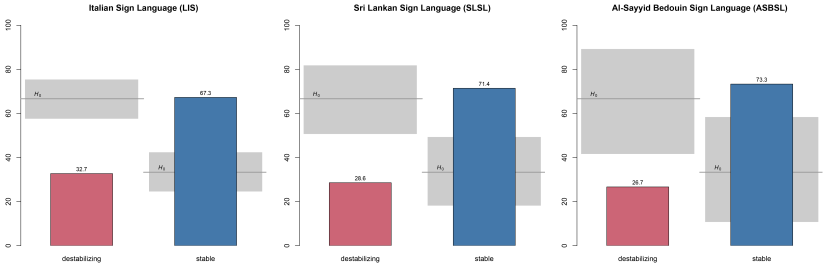
Signs can be multiaxial. For example, PACK in ASL would be coded at +LR and −UD.

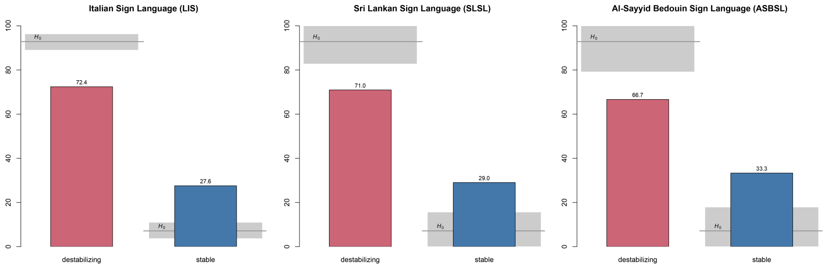
# Our second study: Results

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



# Our second study: Results

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



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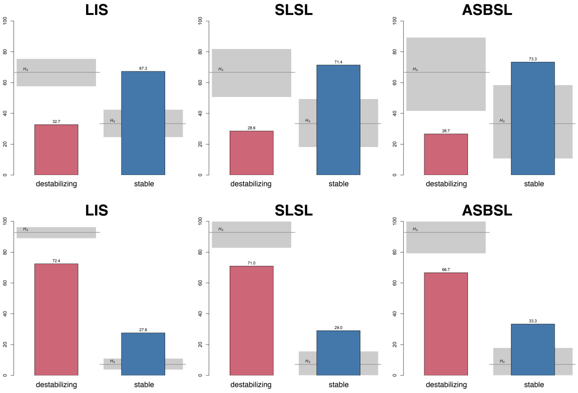
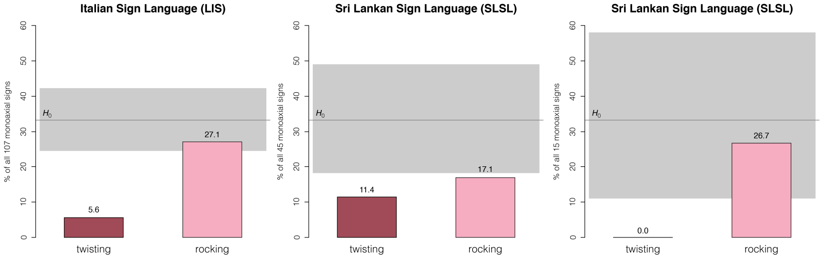


# Our second study: Results

We find that for both monoaxial and multiaxial signs, in all three languages, stable signs are more common than would be expected by chance frequency, and thus, destablizing signs are less common than would be expected by chance frequency.
First prediction confirmed!

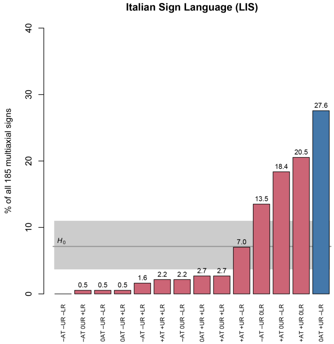
# Our second study: Results

Monoaxial movements that induce torso rocking (+AT and −UD) are more common than those that induce torso twisting (+LR and −AT).



# Our second study: Results

Multiaxial signs are rather complicated. . .



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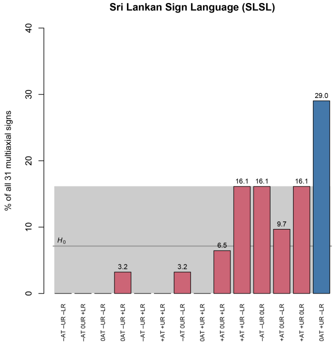
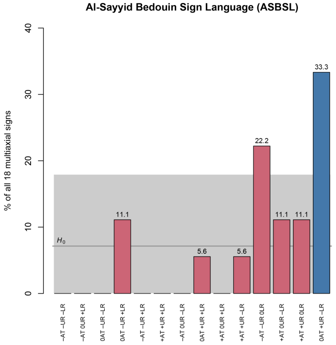
SLSL and ASBSL have too few signs to get solid results. . .



# Summary

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- average amount of freezing versus grafting of a joint (MCU) depends on joint proximity to torso (and thus, amount of mass being moved): shoulder freezes most and grafts least, then the elbow, then the radioulnar, then the wrist
- base and interphalangeal get a pass, because they are hand-internal and thus used for handshape, which is a separate concern from articulatory ease

Reactive effort is a previously unstudied facet of articulatory effort that needs to be distinguished from active effort and can really only be studied by looking at sign languages. It is reduced in the lexicons of LIS, SLSL, and ASBSL, following the same mathematical pattern (which suggests a cross-linguistic pattern since they are unrelated):

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- stable movements are more common — and destabilizing movements less common — than would be expected by random chance
- rocking movements may be more common than twisting movement, but more data is needed

**Thank you!**

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