Articulation versus perception in sign language movement

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Roadmap of the talk

Background

Sign language articulators

There are two main categories of active articulators in sign:

manual articulators (arms, hands, fingers, thumbs)

nonmanual articulators (eyebrows, nostrils, lips, tongue, head, torso)

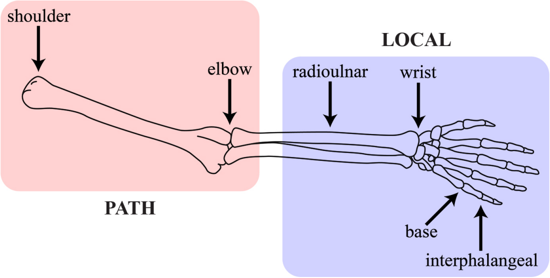
The focus of this talk is on the manual articulators, though nonmanuals are also important to sign and warrant their own analysis.

Manual movement

There are two main categories of movement of the manual articulators:

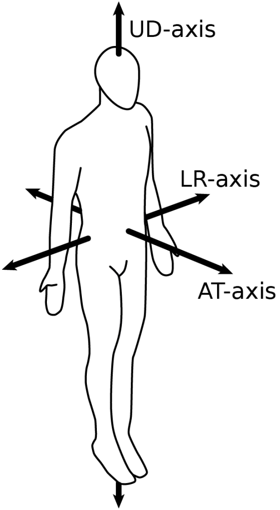
path movement is movement at the shoulder or elbow joints (e.g. ASL STAY and SAME)

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



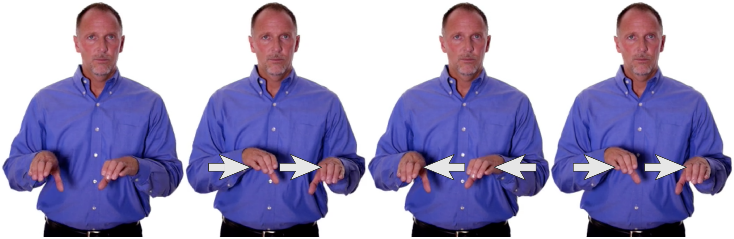
Axes of movement

Sanders and Napoli (2016a) introduce notation for three cardinal axes of movement (**away-toward (AT)**, **up-down (UD)**, **left-right (LR)**), and for two-handed signs, the relative direction of the hands: $+$ for the same direction, $-$ for the opposite direction, and 0 for no movement.



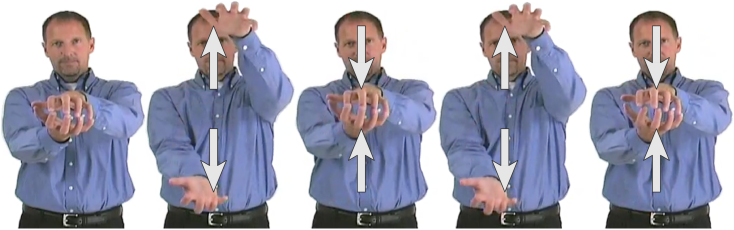
Axes of movement

For example, the movement in ACTIVITY in ASL is $+$LR, since the hands move in the same direction along the LR-axis.



Axes of movement

Meanwhile, the movement in ALLIGATOR in ASL is $-$UD, since the hands move in opposite directions along the UD-axis.



Signs like ACTIVITY and ALLIGATOR, in which movement occurs along only one axis, are called **monoaxial**.

Axes of movement

Signs can also be **multiaxial.** For example, the movement in BICYCLE in ASL is $-$AT $-$UD 0LR.

Data

Spreadthesign (STS) is a large online database of signs maintained by the European Sign Language Centre in Örebro, Sweden. STS contains over 400,000 total videos from over 30 sign languages, mostly from Europe, though other regions are also represented.

Data

For this study, 500 English glosses were randomly selected from STS. For each gloss, if a language had a sign for that gloss that involved **free, simple or retraced two-handed movement** (i.e. not polysyllabic, not a compound, etc.), the sign was coded for both path and local movement along the three cardinal axes.

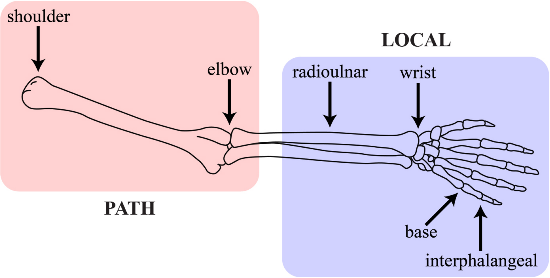
The final data set contains **3,192 total signs** from **33 languages** for **429 individual glosses**. Note: some languages in STS had no suitable signs for any of the 500 glosses, and some glosses had no suitable signs in any language in STS. Some languages in the data set are distinctly underrepresented but are included here for completeness.

Big thanks to Andrei Munteanu for coding!

Path versus local movement

Path versus local movement

Path movement requires moving a greater amount of mass than local movement does, so it requires more articulatory effort, but path movement is larger and thus more perceptually distinctive than local movement (cf. Napoli et al. 2014).



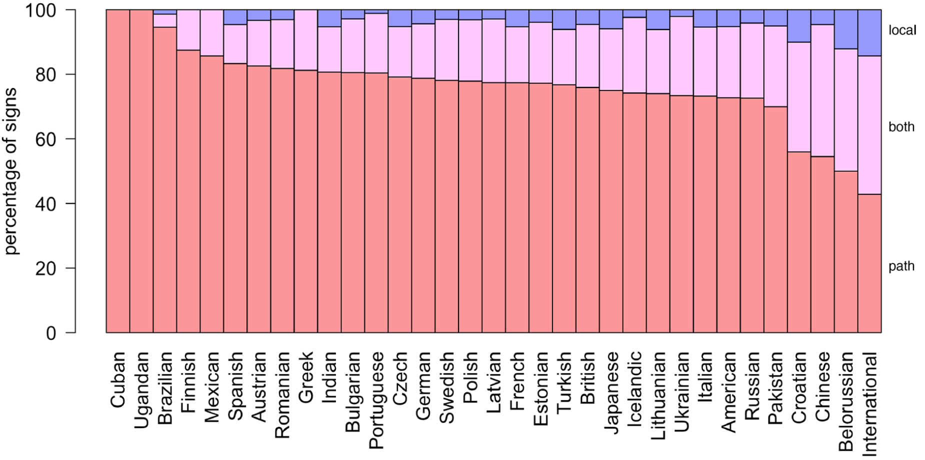
Path versus local movement

Thus, we can get a sense of the overall importance of articulatory ease versus perceptual distinctiveness in a sign language by comparing the amount of path movement and local movement in its lexicon:

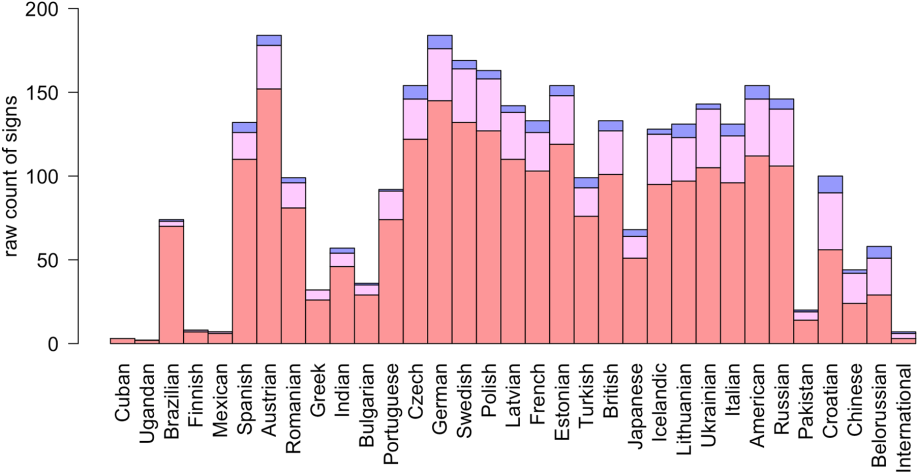
If **path** movement is more common, then **perceptual distinctiveness** is more important than articulatory ease.

If **local** movement is more common, then **articulatory ease** is more important than perceptual distinctiveness.

Results (proportions)



Results (raw)


raw count of signs
0
50
100
150
200
Cuban
Ugandan
Brazilian
Finnish
Mexican
Spanish
Austrian
Romanian
Greek
Indian
Bulgarian
Portuguese
Czech
German
Swedish
Polish
Latvian
French
Estonian
Turkish
British
Japanese
Icelandic
Lithuanian
Ukrainian
Italian
American
Russian
Pakistan
Croatian
Chinese
Belorussian
International

Conclusions

In every language, the amount of path movement in the lexicon is much larger than the amount of local movement (whether combined movement is excluded or grouped with both), so there seems to be a **cross-linguistic preference for path movement**, with approximately 76.6% of the signs in a given language's lexicon having path movement only, and only 4.1% having local movement only.

Thus, at least at the level of path versus local movement, **perceptual distinctiveness is cross-linguistically more important** than articulatory ease.

Reactive effort

Torso stability

Previous work by Sanders and Napoli (2016a,b) identifies **reactive effort** as a type of articulatory effort distinct from the active effort used to move an articulator.

Sanders and Napoli define reactive effort as the effort used to isometrically resist incidental movement of one part of the body caused by movement elsewhere in the body.

For manual movement in a sign language, reactive effort 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.

Torso stability

Reactive effort is important in general because humans generally prefer to maintain an upright, forward-facing torso orientation.

Reactive effort is also important in sign specifically, 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.

Torso stability

Sanders and Napoli (2016b) look at the lexicons of the languages in STS and find that **stable** path movements (those that induce no torso movement, i.e. only along the $+$UD- and/or $-$LR-axes) are cross-linguistically **over-represented** in comparison to destabilizing movements (those that induce either twisting or rocking of the torso).

Comparison between path and local movement

Since local movement involves smaller masses, it does not have the same ability to affect torso stability, so $+$UD and $-$LR movement should be less common in local movement than in path movement.

It is hard to get statistically significant results with this data set, because no sign language has more than 10 signs with local movement only. However, we can still see a general pattern.

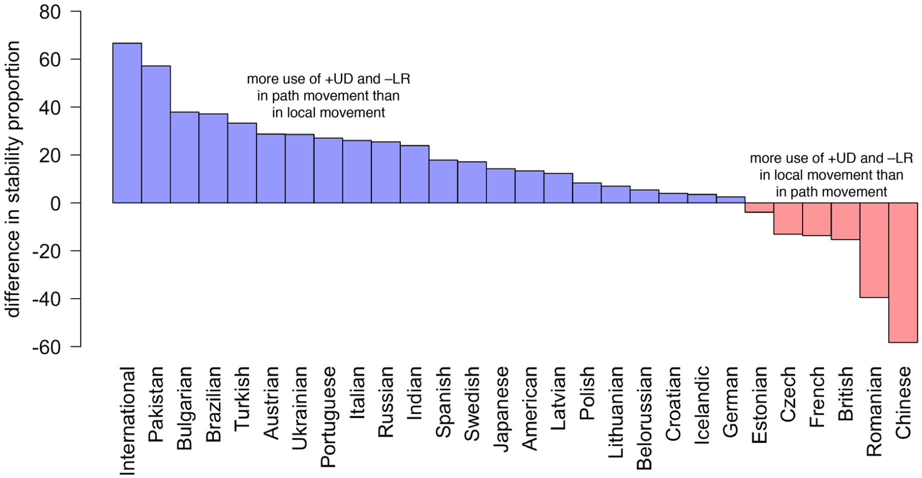
Comparison between path and local movement

For each language, I looked at signs with only path movement and only local movement, and for each, calculated the percentage of those with $+$UD and/or $-$LR movement only, and then took the difference:

$$\frac{+\text{UD}/-\text{LR path only}}{\text{all path only}} - \frac{+\text{UD}/-\text{LR local only}}{\text{all local only}}$$

A positive difference indicates that $+$UD and $-$LR are used more in path movement than in local movement, as predicted.

Results



difference in stability proportion
80
60
40
20
0
-20
-40
-60
more use of +UD and –LR in path movement than in local movement
more use of +UD and –LR in local movement than in path movement
International
Pakistan
Bulgarian
Brazilian
Turkish
Austrian
Ukrainian
Portuguese
Italian
Russian
Indian
Spanish
Swedish
Japanese
American
Latvian
Polish
Lithuanian
Belorussian
Croatian
Icelandic
German
Estonian
Czech
French
British
Romanian
Chinese

Conclusions

In 22 out of 26 languages, the percentage of $+$UD and/or $-$LR movements among signs with only path movement is larger than the same percentage for signs with only local movement. Thus, there seems to be a **stronger cross-linguistic preference for stability in path movement** than in local movement.

This makes sense, because destabilizing movements require additional reactive effort, and this effect is greater for path movement than for local movement.

However, we also need to consider how this might relate to perceptual distinctiveness, since some directions of movement are more distinctive than others.

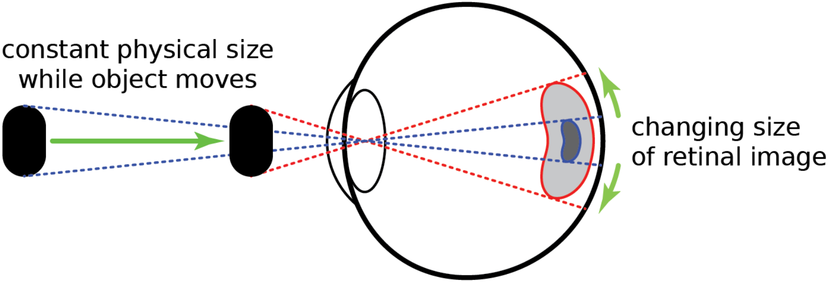
Perceptual distinctiveness

Motion in depth

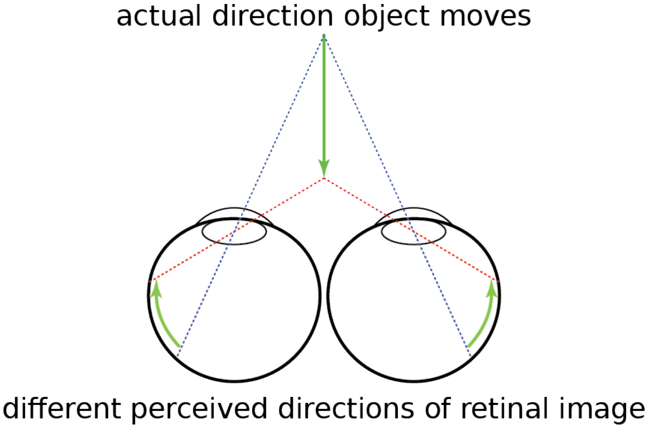
A notable example of how direction of movement matters for perceptual distinctiveness is how **motion in depth** (movement along the AT-axis) is less perceptually distinct than vertical (UD) or horizontal (LR) movement (Regan et al. 1986, Regan and Kaushal 1994).

This is because we view UD and LR movements directly in our field of vision (when something moves upward, we actually see that trace of movement across our retina), but **we view AT movement indirectly and must infer it from other visual cues**, such as change in apparent size and binocular disparity.

Change in apparent size with AT movement



Binocular disparity with AT movement



Comparison between path and local movement

Thus, we would expect that AT movement should be the rarest movement. In previous work (Sanders 2018), I found weak evidence that path movement along the AT-axis is indeed slightly under-represented in comparison to movement along the other axes, as expected.

Given that local movement is smaller than path movement, and thus already inherently harder to perceive, we might expect this effect to be even stronger for local movement. That is, AT movement should be less common in local movement than in path movement.

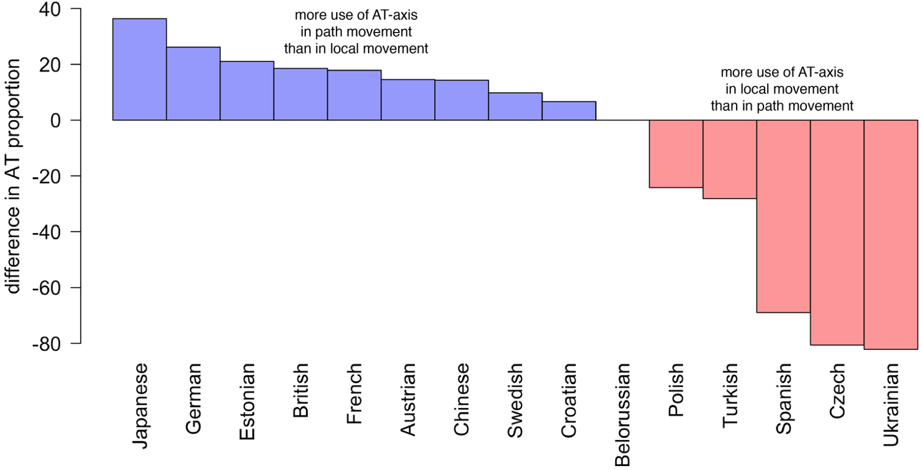
Comparison between path and local movement

I calculated a similar differential as before, focusing on AT movement in monoaxial signs:

$$\frac{\text{AT path only}}{\text{all path only}} - \frac{\text{AT local only}}{\text{all local only}}$$

A positive result indicates that AT movement is used more in path movement than in local movement, as predicted.

Results (monoaxial)



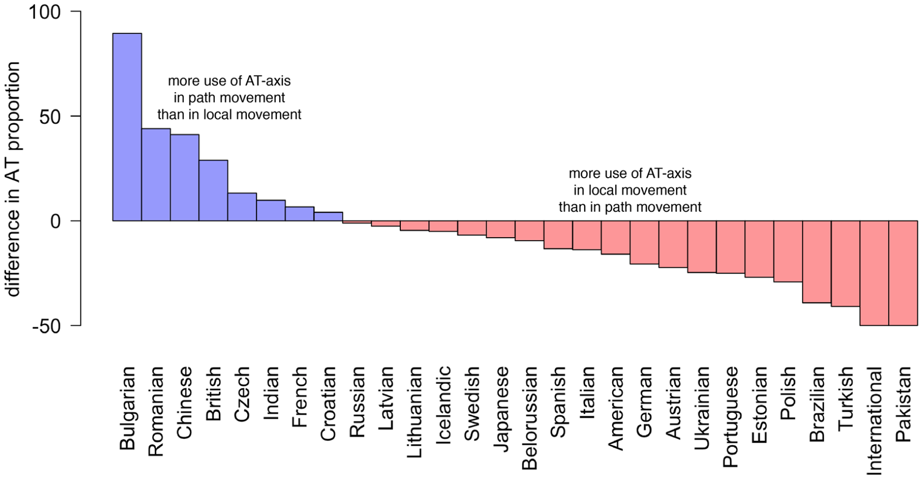
Conclusions (monoaxial)

In 9 out of 15 languages, the percentage of AT movements among monoaxial signs with only path movement is larger than the same percentage for monoaxial signs with only local movement. Thus, there seems to be a **stronger cross-linguistic avoidance of monoaxial AT movement in local movement** than in path movement.

This makes sense, because AT movement is harder to perceive, and this effect is greater for small local movement than for large path movement.

However, the results only hold weakly, and only for monoaxial signs. When the same differential is calculated for multiaxial signs, AT movement is more frequent in local movement.

Results (multiaxial)



Conclusions (multiaxial)

In only 8 out of 28 languages, the percentage of AT movements among multiaxial signs with only path movement is larger than the same percentage for multiaxial signs with only local movement. Thus, there seems to be a **stronger cross-linguistic avoidance of multiaxial AT movement in path movement** than in local movement.

But this is the opposite result for monoaxial signs, contradicting the idea that perceptual weak AT movement should be rarer in local movement.

Conclusions (multiaxial)

However, the results do make sense!

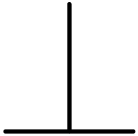
For multiaxial movement, failing to perceive AT movement does not mean failing to see all movement, whereas that would be the case for monoaxial signs. Thus, we might expect that other factors (such as articulatory ease) may play a stronger role with respect to AT movement in multiaxial signs.

And as it turns out, both types of $+$AT and $-$AT movement are destabilizing (rocking and twisting, respectively), while UD and LR movements have one stable ($+$UD, $-$LR) and one destabilizing type ($-$UD, $+$LR).

Perceptual distinctiveness redux

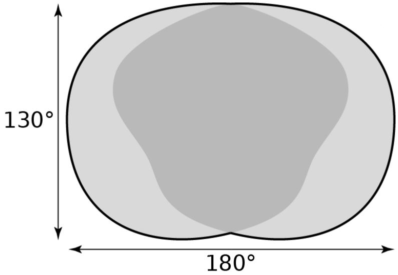
The horizontal-vertical illusion

Although they are directly observed, UD and LR movement are perceived slightly differently from each other, as in the so-called **horizontal-vertical illusion** (Fick 1851, Bailey and Scerbo 2002), in which vertical distances and movements are perceived as longer than those in the horizontal dimension:



The horizontal-vertical illusion

This illusion can be explained by the geometry of our ambinocular visual field (Künnapas 1957), which is the union of our roughly circular (Webb 1964, Parker and West 1973) individual monocular fields of view, resulting in a roughly elliptical field because of the horizontal placement of the eyes:



Comparison between path and local movement

Thus, we would expect that LR movement should be rarer than UD movement. However, in the same previous work as for motion-in-depth (Sanders 2018), I found no evidence that path movement along the LR-axis is under-represented in comparison to movement along the UD-axis.

Given again that local movement is smaller and harder to perceive than path movement, we might expect this effect to show up for local movement at least. That is, LR movement should be less common in local movement than in path movement.

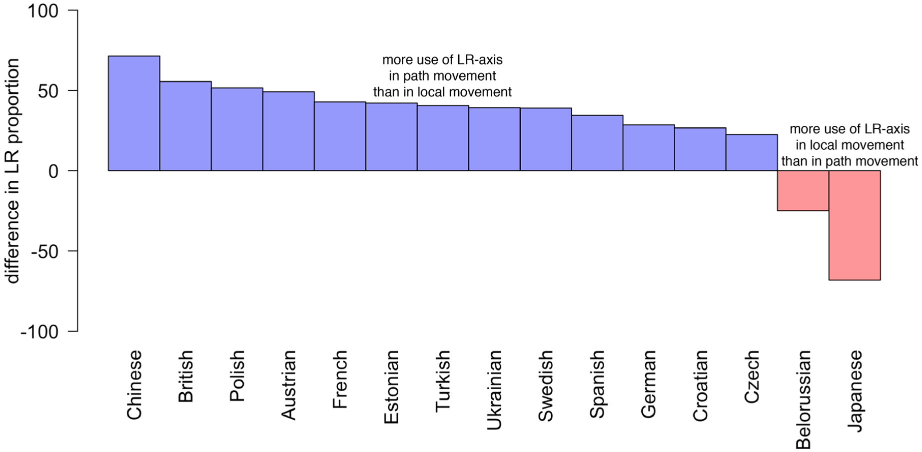
Comparison between path and local movement

I calculated a similar differential as before, focusing on LR movement in monoaxial signs:

$$\frac{\text{LR path only}}{\text{all path only}} - \frac{\text{LR local only}}{\text{all local only}}$$

A positive result indicates that LR movement is used more in path movement than in local movement, as predicted.

Results (monoaxial)



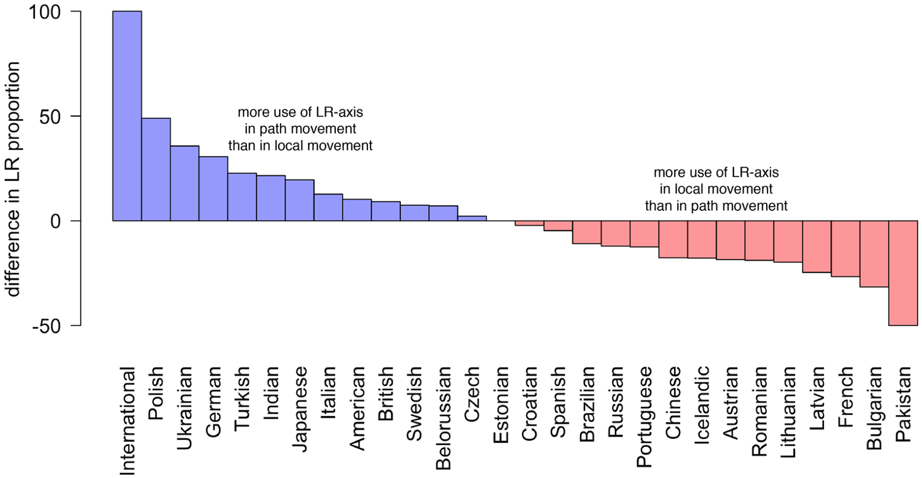
Conclusions (monoaxial)

In 13 out of 15 languages, the percentage of LR movements among monoaxial signs with only path movement is larger than the same percentage for monoaxial signs with only local movement. Thus, there seems to be a **stronger cross-linguistic avoidance of monoaxial LR movement in local movement** than in path movement.

This makes sense, because LR movement is harder to perceive than UD movement, and this effect is greater for small local movement than for large path movement.

As before, we expect this effect to go away in multiaxial signs, because perception of movement does not rely on a single axis of movement.

Results (multiaxial)



Conclusions (multiaxial)

In 13 out of 28 languages, essentially half, the percentage of LR movements among multiaxial signs with only path movement is larger than the same percentage for multiaxial signs with only local movement. Thus, there seems to be **no cross-linguistic difference in avoidance of multiaxial LR movement between path and movement**.

This is expected based on what we saw with AT movement: differences in axes of movement between path and local movement based on perceptual distinctiveness are only relevant for monoaxial signs, when only a single axis is available for perception. In multiaxial signs, the perceptual distinctiveness of any single direction of movement is less critical.

Summary

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- **path movement is cross-linguistically more common than local movement**; the greater perceptual distinctiveness of the larger paths outweighs the increased articulatory effort of moving larger masses
- **$+$UD and $-$LR are more common in path movement than in local movement**; $+$UD and $-$LR keep the torso stable, so they require less reactive effort, but this more of a factor for the larger masses involved in path movement

Summary

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Summary

- **AT movement is more common in path movement than in local movement**; AT movement (motion-in-depth) is the hardest to see, and it is even harder for the smaller movements in local movement
- similarly, **LR movement is more common in path movement than in local movement**; LR movement is harder to see than UD movement due to the horizontal-vertical illusion
- ... **but these two perceptual effects only apply to monoaxial movement**, where the perceptual distinctiveness of the only direction is crucial, since failing to perceive it would result in failing to see any movement at all

Thank you!

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