Signing often involves full, upper-body movement.

EUGENE TANNER PHOTOGRAPHY, LLC

Signs of Efficiency

Maintaining torso stability affects sign language vocabulary.

By Nathan Sanders and Donna Jo Napoli

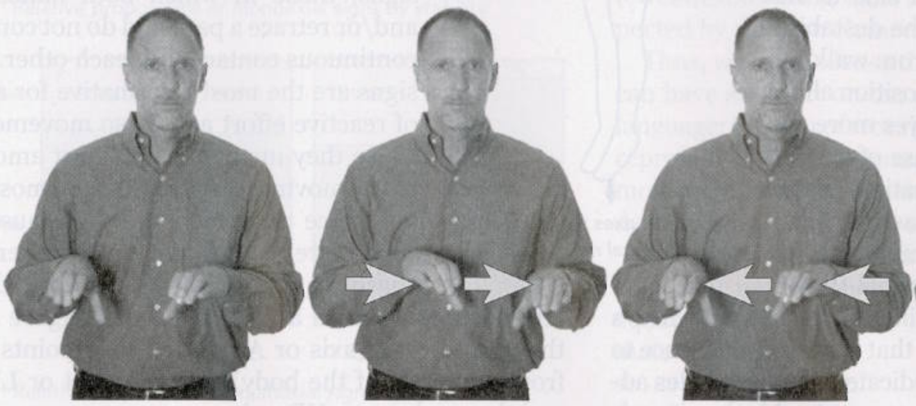
Humans seek out efficient ways of accomplishing any task, including the task of communication. Languages are not perfectly uniform systems. Some linguistic structures are more common than others. One factor for why a given linguistic structure may be more or less common than another is the amount of physical effort it takes to articulate it.

Although linguists have studied the drive for ease of articulation extensively, there is still much to learn, particularly about sign languages, which have been rigorously analyzed only for a few decades as opposed to the thousands of years spent analyzing spoken languages. Because sign languages have different major articulators (arms and hands instead of lips and tongue), they provide an opportunity to discover aspects of effort that are not as apparent in spoken languages. In particular, the arms are so massive that their movement can readily destabilize the torso by causing it to twist (in the sign for "activity" in American Sign Language [ASL], see opposite page, top), rock side-to-side (as in the ASL sign for "maybe," opposite page, middle), or rock back and forth (as in the ASL sign for "teach," opposite page, bottom). This twisting and rocking of the torso is relatively more physically demanding, so signers will ordinarily expend what we call "reactive effort" to counteract destabilization.

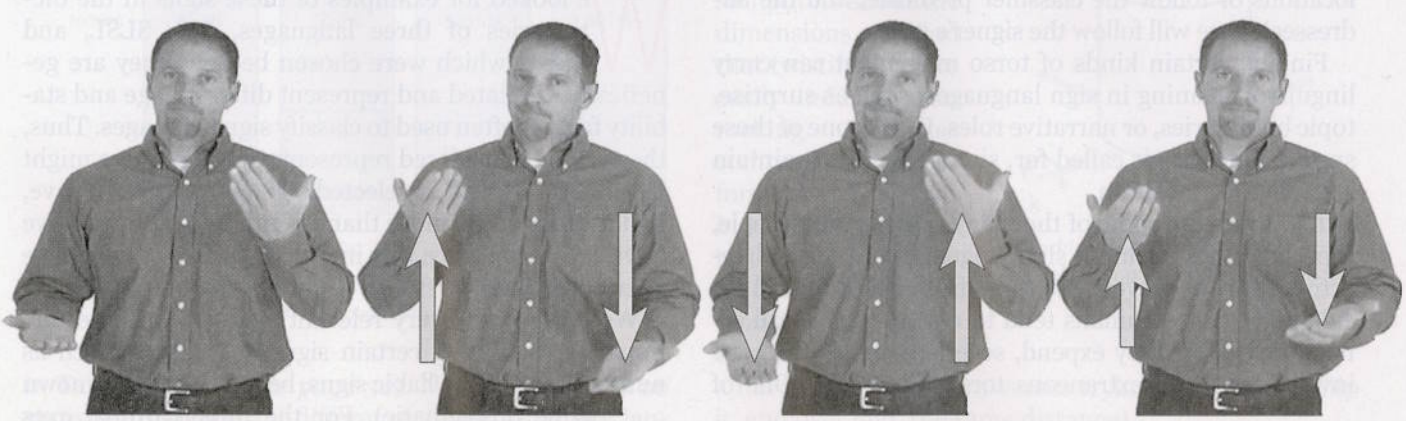
But all effort expenditure is costly, so people tend to decrease the kinds of movements that require reactive effort. This is what we have found in three sign languages: the dialect of Italian Sign Language (*lingua dei segni italiana*, henceforth LIS) used in the Sicilian province of Catania; Sri Lankan Sign Language (SLSL); and Al-Sayyid Bedouin Sign Language (ABSL), a village sign language of southern Israel. In these languages, arm movements that induce rocking of the torso are underrepresented in the lexicon, and those that induce twisting are rarer still. These facts follow directly from our notion of reactive effort.

Movement of the torso is typically activated via various muscles in the torso itself. However, movement in some other body part can also externally induce the torso to move. For example, strongly waving a hand as if signaling a distant friend can make the torso rock side to side. We can resist this incidental rocking by using the torso muscles to isometrically hold the torso fixed. Reactive effort is the effort expended for such resistance. Since sign languages regularly make use of path movement (movement of the forearm or entire arm so that the hand traces a path through space), and path movement readily induces extraneous torso movement, we may find many instances in which signers need to exert reactive effort.

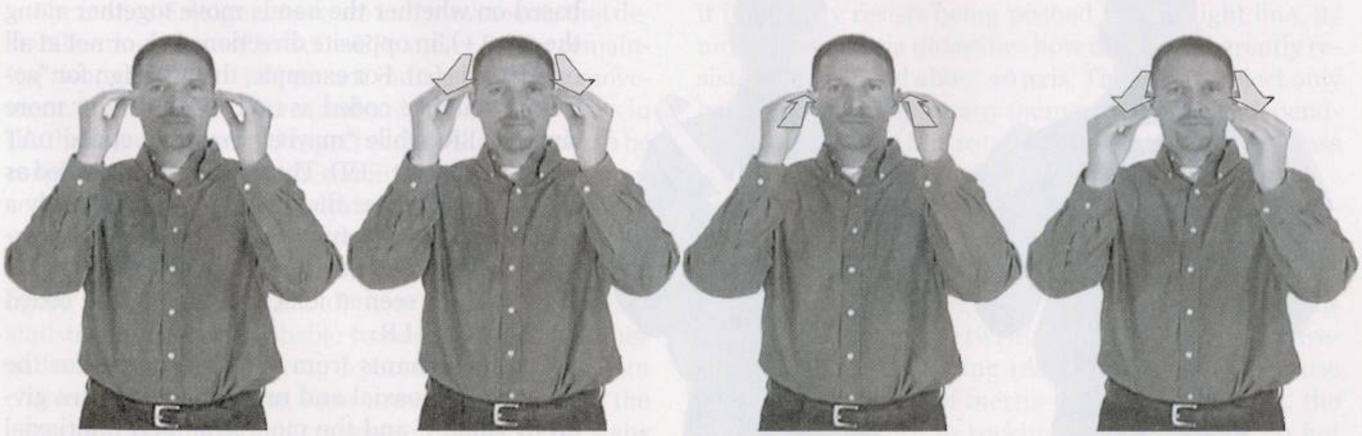
In theory, such incidental torso movement could just be accepted and not resisted by expending reactive effort. However, the torso and its stability are important to human biology and social behavior. By default, humans keep the torso erect and facing forward in ordinary



Potential twisting induced by signing the word "activity" in ASL



Potential left-right rocking induced by signing the word "maybe" in ASL



Potential front-back rocking induced by signing the word "teach" in ASL

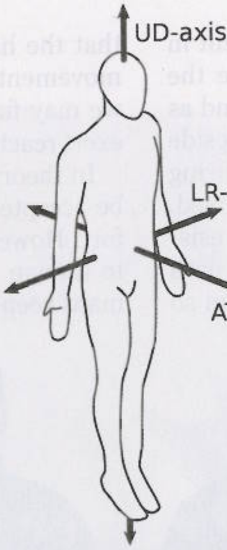
EUGENE TANNER PHOTOGRAPHY, LLC

circumstances, in part because of how we evolved to walk on two legs. Walking on two legs induces twisting of the torso, which destabilizes the body. To counteract such destabilization, humans not only swing the arms, but we also evolved a large and strong iliopsoas muscle (hip flexor) to keep the torso stable. In contrast, the other great apes maintained a smaller iliopsoas muscle, so they instead rock side to side when bipedal to counteract the destabilizing effects of torso twisting from walking.

Additionally, a fixed torso position allows humans to see each other's eyes more easily, which is important because of the role the eyes play in communicating certain kinds of information, such as displaying a larger sclera area to communicate fear and pointing our eyes at potential threats. The eyes are also important in sign languages: when a signer uses indexicals (words that vary with reference to the context) or a classifier predicate (which provides additional information about a noun or verb), the signer's gaze will typically move to at least one of the indexed locations or follow the classifier predicate, and the addressee's gaze will follow the signer's gaze.

Finally, certain kinds of torso movement can carry linguistic meaning in sign languages, such as surprise, topic boundaries, or narrative roles. Unless one of these special functions is called for, signers tend to maintain a stable torso position.

The above are some of the many reasons why people, especially those using a sign language, will expend reactive effort to prevent the torso from being moved incidentally. Since humans tend to reduce the overall articulatory effort they expend, several strategies may be invoked to avoid extraneous torso movement. One of those is that sign languages may reduce the overall amount of destabilizing articulations (those that induce the torso to twist or rock), obviating the need to expend as much reactive effort.

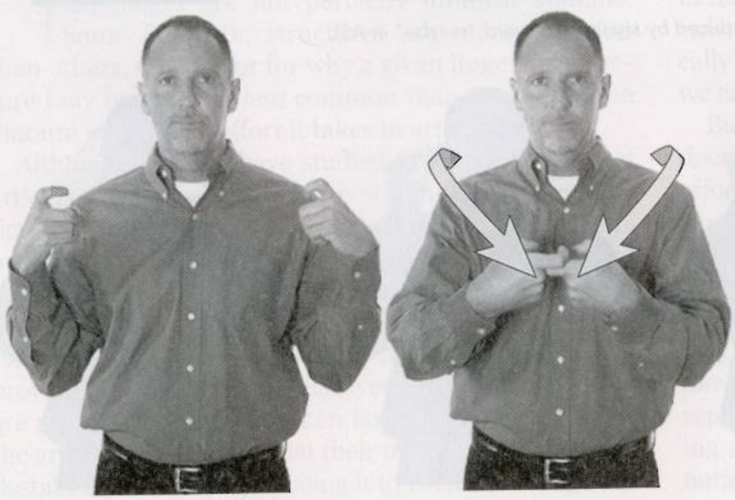


Cardinal axes for describing manual movement

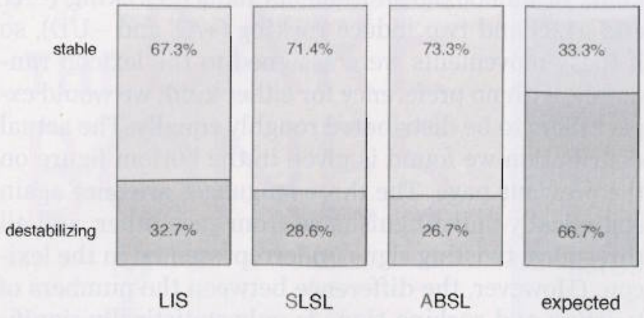
In order to determine whether, and to what extent, sign languages reduce the overall amount of destabilizing articulations, we considered a particular class of signs, those in which both hands trace and/or retrace a path and do not come into continuous contact with each other. These signs are the most informative for a study of reactive effort and torso movement because they involve the greatest amount of freely moving mass, so they are most likely to induce torso movement. Because their paths are traced in three-dimensional space, we can describe them using the system of three cardinal axes shown in the figure at left: the away-toward axis or AT-axis (which points to the front and back of the body), the left-right or LR-axis, and the up-down or UD-axis.

We looked for examples of these signs in the dictionaries of three languages, LIS, SLSL, and ABSL, which were chosen because they are genetically unrelated and represent different age and stability factors often used to classify sign languages. Thus, they can be considered representative of how we might expect any arbitrarily selected sign language to behave, and indeed, of the more than twenty sign languages we have examined since this initial study, the results have been consistent.

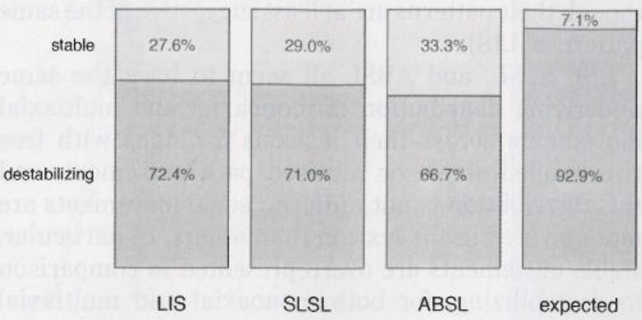
We catalogued every relevant sign in the three dictionaries (excluding certain signs in advance, such as numbers and polysyllabic signs, because they are known to be problematic). For the three cardinal axes for movement (AT, UD, LR), we coded each sign based on whether the hands move together along the axis (+), in opposite directions (–), or not at all on that axis (o). For example, the ASL sign for "activity" would be coded as oAT oUD +LR, or more simply +LR, while "maybe" would be coded oAT –UD oLR or just –UD. These signs are classified as monoaxial, because the hands move along only a single axis. Signs may instead be multiaxial, moving along two or three axes, as in the ASL sign for "Spanish" (as seen at left), which would be coded as +AT +UD –LR.


Multiple axes of movement are required to sign "Spanish" in ASL.

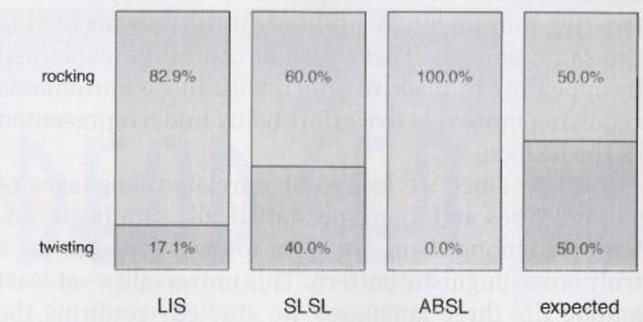
The final counts from our dictionaries for the relevant monoaxial and multiaxial signs are given in Table 1, and the monoaxial and multiaxial signs are broken down by individual movements



Relative proportions of monoaxial signs by stability



Relative proportions of multiaxial signs by stability



Proportions of destabilizing monoaxial signs by torso movement

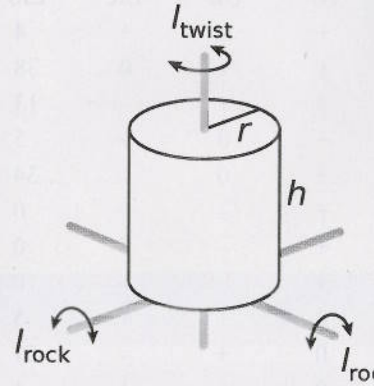
in Tables 2 and 3 (*see page 32*). Note that there is no statistically significant difference among the three languages in how the movements are distributed.

For monoaxial signs, there are four movements that destabilize the torso: +AT, −AT, −UD, and +LR. The remaining two, +UD and −LR, do not induce any torso movement. If movements were randomly assigned to signs in the dictionary, we would expect each of the six types to be roughly equal, so that the destabilizing signs would represent about two-thirds of the lexicon, while the stable signs would only be about one-third. However, when we calculate the actual proportions in our data (graphed in the top figure above), we find that all three languages are again statistically indistinguishable from each other, but they pattern very differently from expectations due to random chance: the destabilizing signs are much rarer than the expected two-thirds, and consequently, the stable signs are much more common than the expected one-third.

Similar results obtain for the multiaxial signs (see middle figure at left). There are twenty multiaxial combinations, and only one of those is stable (0AT +UR −LR). Of the remaining nineteen, six are extremely cognitively difficult, so they are excluded from consideration (none of the languages we studied had examples of these anyway), leaving thirteen destabilizing multiaxial signs. Just as with monoaxial signs, the three languages all pattern the same way as each other, but have fewer destabilizing signs and more stable signs than expected by random chance.

Thus, we see evidence that avoidance of reactive effort can have an effect on the nature of the lexicon of a sign language: the more favorable stable movements are overrepresented in the lexicon, because they induce no torso movement and thus require no reactive effort, while the destabilizing movements are underrepresented.

The story becomes more complex when we acknowledge that not all destabilizing movements are created equal. If we approximate the human torso as a cylinder (in the figure at right), using reasonable assumptions about the dimensions, we find that twisting is more easily induced than rocking. It takes comparatively less force to cause a cylinder like the torso to twist than it does to cause it to rock (consider the difference between rolling a full keg across a lawn versus trying to repeatedly flip it, end over end, the same distance).



Cylindrical approximation of the torso for calculating moments of inertia for twisting versus rocking

Just as the mass of an object quantifies how much it inherently resists being pushed in a straight line, its moment of inertia quantifies how much it inherently resists being rotated about an axis. Though an object only has one mass, it has many moments of inertia, depending on which axis it is rotated around and how its mass is distributed, among other factors.

Based on the proportions of the human body, particularly the fact that the torso is narrower than it is tall, we find that the torso has less inherent resistance to twisting than it does to rocking, so moving the arms can more easily induce twisting. All destabilizing movements require expending reactive effort, but because the torso's moment of inertia is larger for rocking, the inherent resistance to rocking is larger, so we do not have to expend quite as much reactive effort. If the pat-

	LIS	SLSL	ABSL
MONOAXIAL	107	35	15
MULTIAXIAL	185	31	18
TOTAL	292	66	33

Table 1. Number of signs with free two-handed single or retraced path movement.

	LIS	SLSL	ABSL
+AT	12	2	1
–AT	5	4	0
+UD	30	10	7
–UD	17	4	3
+LR	1	0	0
–LR	42	15	4

Table 2. Distribution of monoaxial signs by axial movement.

AT	UD	LR	LIS	SLSL	ABSL
+	+	+	4	0	0
+	+	0	38	5	2
+	+	–	13	5	1
+	0	+	5	2	0
+	0	–	34	3	2
+	–	+	0	0	0
+	–	0	0	0	0
+	–	–	0	0	0
0	+	+	5	0	1
0	+	–	51	9	6
0	–	+	1	1	2
0	–	–	1	0	0
–	+	+	0	0	0
–	+	0	0	0	0
–	+	–	0	0	0
–	0	+	1	0	0
–	0	–	4	1	0
–	–	+	3	0	0
–	–	0	25	5	4
–	–	–	0	0	0

Table 3. Distribution of multiaxial signs by axial movement.

tern of stable and destabilizing signs truly represents the effects of reactive effort, then we would expect sign languages to show a similar pattern for rocking and twisting, with rocking signs overrepresented in comparison to twisting signs.

Though our data are not quite as robust on this matter, the predicted pattern is still evident, at least for monoaxial signs (multiaxial signs are too complex to analyze with regard to twisting versus rocking). Two kinds of monoaxial movements induce twisting (–AT and +LR) and two induce rocking (+AT and –UD), so if these movements were assigned to the lexicon randomly, with no preference for either kind, we would expect them to be distributed roughly equally. The actual distribution we found is given in the bottom figure on the previous page. The three languages are once again statistically indistinguishable from each other, and all three have twisting signs underrepresented in the lexicon. (However, the difference between the numbers of twisting and rocking signs is only statistically significant in LIS; the data for SLSL and ABSL are too sparse, though their patterns are at least suggestive of the same pattern as LIS).

LIS, SLSL, and ABSL all seem to have the same underlying distribution of monoaxial and multiaxial movements across their lexicons for signs with free two-handed single or retraced path movement, and this distribution is not uniform: some movements are more favored in the lexicon than others. In particular, stable movements are overrepresented in comparison to destabilizing, for both monoaxial and multiaxial signs, and at least in monoaxial signs in LIS, rocking movements are overrepresented in comparison to twisting movements, with SLSL and ABSL suggesting the same pattern. These results can all be explained by appealing to reactive effort, with those movements requiring more reactive effort being underrepresented in the lexicon.

Further, since we looked at unrelated languages of varying types and found no statistically significant differences among them, we seem to have evidence for a truly cross-linguistic pattern. This universality—at least among the three languages we studied—confirms the idea that reactive effort is at play, since it is based on basic human biology and physics, to which we are all subject, regardless of which language we use. Thus, we expect to find these patterns in other sign languages, and delving deeper, we may find evidence of reactive effort shaping other aspects of language, whether sign or spoken.

This article is adapted from a longer, more technical paper by the same authors: "Reactive effort as a factor that shapes sign language lexicons." *Language* 92, 2 (2016): 275-297.

Nathan Sanders is visiting assistant professor, Department of Linguistics, Haverford College, with joint appointments at Bryn Mawr College and Swarthmore College. **Donna Jo Napoli**, professor of linguistics at Swarthmore College, is also a well-known author of children's fiction.