A gestural basis for the use of height to convey set size in sign languages

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Abstract

Metaphors involving space and orderings have been the target of research on both gesture and the gestural origins of sign languages. In the latter, focus has been on regularities within lexical items and lexical groupings that show ties to existing cultural metaphors, such as the American Sign Language signs TOMORROW and WILL, which both use a forward motion consistent with the metaphor FUTURE IS AHEAD. The present study focuses on the gestural origins of a more abstract metaphoric representation in sign language semantics/pragmatics, beyond the lexicon: the use of the metaphor MORE IS UP to indicate set sizes for purposes of quantifier domain restriction. We report evidence from a production task by English speakers with no sign language experience, using both pantomimed and speech+co-speech gesture prompts. Our results make use of the increasingly abstract space-ordering mapping here to shed new evidence on the grammaticalization relationship between sign and gesture.

Key words

Metaphor, More is Up, American Sign Language, Grammaticalization, Domain Restriction, Pantomime, Co-speech gesture

Biographical Notes

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Introduction

The stable relationships that arise between space and number is a remarkable aspect of human cognition, evidenced frequently through gestures that employ space in regular ways to convey numerical information via metaphors. For example, it is well known that English speakers capitalize on a vertical axis metaphor MORE IS UP, both in metaphoric speech as well as in co-speech gesture. Lakoff and Johnson (1980) were among the first to claim that the vertical axis is used to indicate quantity in English; for example, it is acceptable for English speakers to refer to an increase in stock prices by saying that "prices went up." More recently, Winter, Perlman and Matlock (2013) discussed further evidence from spontaneous gesture production by analyzing video from a television news archive, where quantity was gestured either along the lateral axis, with smaller quantities to the left and larger to the right, or along the vertical axis, with smaller quantities lower down and larger quantities higher up.

Explicit experimental evidence has also supported the existence of a MORE IS UP mapping. Langston (2002) found that comprehension was worse for sentences inconsistent with the proposed MORE IS UP metaphor than those consistent with the metaphor. For example, the sentence "Coke was placed above Sprite because it has less caffeine" (inconsistent with MORE IS UP) elicited more difficulties in comprehension than "Coke was placed below Sprite because it has less caffeine" (consistent with MORE IS UP). Sell and Kaschak (2012) extended this finding by requiring participants to provide a spatial response by pressing a button on a keyboard that was either higher or lower on a vertical axis, or to the left or right on a horizontal axis. Participants were asked to read 6-sentence stories that

included stimuli such as "More runs were being scored this game," or "Less runs were being scored this game." They found that participants were significantly slower to respond when required to make a response that was in contradiction with the MORE IS UP metaphor, further strengthening the evidence for the cognitive effects of the metaphor in English speakers.

In this work we bring together experimental evidence of the MORE IS UP spatial mapping in English with recent research from sign language linguistics. Specifically, this research shows that in American Sign Language (ASL), MORE IS UP presents itself not only as a metaphor for relative numerosities of conceptual items, as in English, but also for set/subset relationships where increasingly larger/super sets are articulated increasingly higher in sign space. Such sets are used as arguments of linguistic phenomena in ASL such as quantifiers and verbs, a use we describe in more detail below. This is a much more (a) abstract and (b) grammatical use of MORE IS UP. The quantity is not merely a number on a number line that can be mapped directly onto the vertical axis, but rather an extension of this principle to set cardinality: if one set contains another, it should be higher in vertical space than its subset. Furthermore, in ASL this use of height participates fully in the grammar, being permitted in some syntactic contexts (determiner phrases, such as on pronouns and following quantifiers) and not others (bare noun phrases, uncommon in English but very common in ASL).

The strong evidence for this more abstract extension of the metaphor to ASL raises the question of whether this mapping is also available in the broader culture in the US in the gestures of English speakers. If so, this would suggest that ASL borrowed the extended metaphor and grammatical restrictions from English; if not, this suggests that there isn't a

gestural basis for the use in ASL; if the link is indirect, or perhaps if English speakers have a less regular use than signers, this could provide a new insight into the process of grammaticalization from gesture to sign, in the brand new domain of formal semantics. To foreshadow our conclusions, our results support the last of these hypotheses: we present new evidence that hearing English speakers with no knowledge of ASL in fact do use MORE IS UP to indicate sets and subset relationships, but do so in a slightly different and less regularized pattern than ASL signers, which supports the hypothesis that this highly abstract and grammaticized use of vertical height for set reference in ASL may have its roots in the gestural productions of hearing non-signers.

Sign language grammaticalization of gesture

There is strong evidence globally for historical borrowing between spoken languages in contact with each other, seen most clearly in the emergence of spoken pidgins and creoles (e.g., Arends, Muysken, & Smith, 1994; Holm, 1989). Is it thus not surprising that sign languages also influence each other during times of extended contact, such as in the merging of French Sign Language (LSF) with the signed system used by residents from Martha's Vineyard, which gave rise to the beginnings of American Sign Language (Lane, Hoffmeister, & Bahan, 1996). More recently, this process of borrowing and grammaticalization has also been extended to the contact that deaf people using sign languages have with the co-speech gestures of hearing people around them (Casey, 2003; Coppola, 2007; Hendriks, 2009; McClave, 2001). In these cases, deaf people using sign language have been shown to capitalize on available gestures in their environment and change them to be more "grammatical" in a variety of ways that make them more suited for

linguistic use. This can be lexical change, such as the adoption of gestural emblems for narrower semantic purposes (e.g., the hearing gesture which accompanies a request in Jordan has been adopted into Jordanian Sign Language (LIU) to mean PLEASE (Hendriks, 2009)), the adoption of facial gestures for grammatical markers of questions in the United States (e.g., McClave, 2001), and arguably the use of gestural/sign space for referential morphology (Casey, 2003; Coppola & So, 2006; Perniss & Özyürek, 2015; So, Coppola, Licciardello, & Goldin-Meadow, 2005).

In many cases, but not all, the adoption of gesture into sign language also involves the addition of grammatical features – that is, the gesture appears in particular forms, uses a particular phonology, and/or appears in particular grammatical environments with specific semantic interpretations that are more conscribed than one would find in hearing gestures within the same culture (e.g., Coppola, 2007, Hendriks, 2009, McClave, 2001). To take again the Jordanian example of PLEASE, the gestural form used by hearing individuals does not have any conscribed, or limited, grammatical use other than accompanying a request – it may be produced before, during, or after the actual request. On the other hand, the LIU sign PLEASE does have a conscribed form – it generally only appears at the beginning of the request, to mark the following as such (Hendriks, 2009).

In the current paper, we hypothesize that MORE IS UP in non-signing contexts may be the substrate of yet another example of these grammaticalization processes. We derive this from recent work which shows that ASL signers capitalize on the MORE IS UP metaphor not just for numerosities, but also to express relative set sizes, and to use these sets to restrict domains for particular quantifiers and verbs (Davidson & Gagne, 2014a, 2014b). This domain information in ASL is two steps more abstract than simply lining up the number

line with the vertical axis, as we already know is done in English speakers' gestures: first, it involves set size cardinalities in a set/superset relationship, not just numbers, and second, it can be then used to restrict quantifier domains, as we discuss below. Given this increased abstractness, it is therefore possible that either the vertical axis in American hearing speakers' co-speech gesture does not contain domain size information and grammaticalization was added when the general (number-line) vertical axis was adopted by the ASL grammar, or, perhaps, the vertical axis is available to hearing gesturers for the expression of relative domain size and ASL applies other possible grammatical rules. In this paper, we look at gestures by American non-signers and compare them to signers of ASL to investigate precisely this relationship between the complex semantics found in ASL and the gestures in the surrounding speech community. First, however, we discuss in more detail the way that height is used to convey domain size in ASL.

Domain Restriction in American Sign Language. Most of the time, language users are remarkably good at situating and calculating language meaning within a particular context. Consider receiving a compliment at a party that "everyone loved your chocolate cake!" In this context, *everyone* likely refers to everyone who ate the dinner in question that involved cake, not everyone in the entire world, most of whom never had a chance to eat the cake. Likewise, you might overhear a teacher remind her students that "everyone needs to do their homework tonight!" In this context, *everyone* is meant to include or *quantify over* just the students, who make up the *domain* of the quantifier. In neither case does *everyone* actually intend to quantify over all possible people, although it might in some very unusual contexts (e.g. noting that *everyone* breathes).

The puzzle of how set sizes (e.g. who do we mean by *everyone*?) become sufficiently restricted in conversation based on their context is the problem of *quantifier domain restriction*. In English, quantifier domain restriction occurs either via pragmatic enrichment that interlocutors need to infer from the context (such as the dinner party guests, the students, or all living things, respectively in our examples), or is marked overtly by adding partitive or relative clauses (*Everyone of the dinner guests, everyone of the students, everyone who is living*, etc.). These same options for domain restriction hold for other quantifiers like *someone (*"someone [that I invited] didn't come to the party!"), *no one* ("no one [of the people at the party] ate chocolate cake!"), and various other natural language quantifiers (*many, few, more than half*, etc.). In this paper, we ask whether English speakers have an additional, as yet undescribed and potentially overlooked, strategy present in their gesture for conveying the relative sizes of quantifier domains by using increasingly higher and wider gestures for increasingly larger domains.

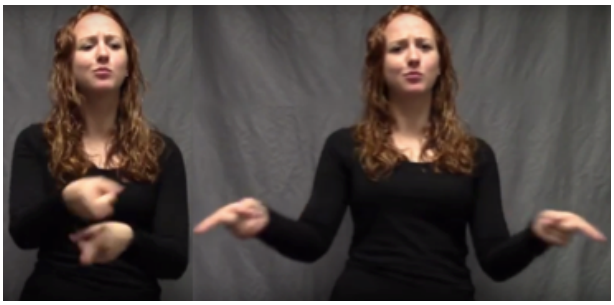
One reason we might expect such a gestural strategy is that space is used in this way to overtly mark the relative sizes of quantifier domains in ASL. Davidson and Gagne (2014) detail how ASL employs the use of space, and vertical height in particular, to convey set size, with increasingly larger sets signed increasingly higher. Figures 1-3 display how an ASL signer can manipulate the height of a quantifier to indicate a change in the set size. In Figure (1), the signer is discussing an investigation of a sickness in a specific area (Africa). In both (1a) and (1b) she signs the same sequence of signs (WANT KNOW WHO IX-$_{arc}$ SICK) with one difference: the IX-$_{arc}$ is signed low in (1a) and high in (1b). This difference leads to a difference in interpretation: in (1a) the signer is saying that they want to know who *in Africa* contracted the virus, while in (1b) they want to know who *in the*

world contracted the virus, where *Africa* is a subset of the whole world. The specific reference for these domains (e.g. Africa, the whole world) is implied from the context, just as in English, but in ASL there is an available additional use of height to distinguish between a smaller salient domain (Africa) and a larger one (the whole world). Similar examples can be found with other quantifiers, including NO ONE (2a-b) and SOMEONE (3a-b).

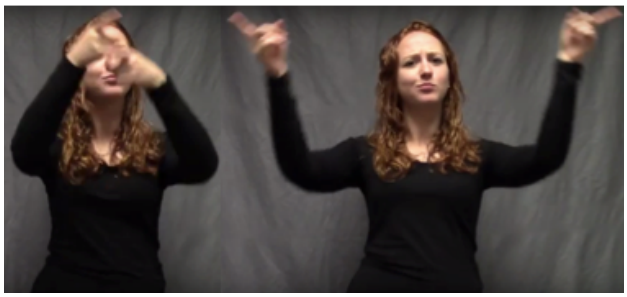
Figure 1. American Sign Language production of **IX-arc** (a sweeping point).

Context: The World Health Organization is investigating the latest Ebola outbreak in Africa.

Sentence: WANT KNOW WHO IX-$_{\text{arc}(\textit{high/low})}$ SICK
'(They[1]) want to know who of *them* (in: *Africa: low –1a)/ (the world: high – 1b)* has gotten sick.'



1a. "They/them in Africa" IX-arc$_{\text{LOW}}$ (smaller set size)



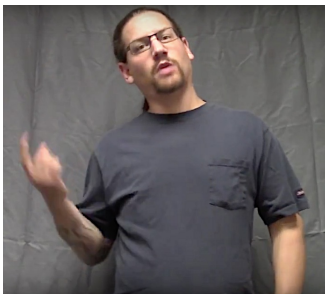
1b. "They/them in the world" IX-arc$_{\text{HIGH}}$ (larger set size)

[1] Like many other languages (but not English), American Sign Language allows an unpronounced subject, known as pro-drop. In this example with pro-drop, the subject is taken to be understood to be the most salient entity and/or most recent subject, the World Health Organization.

Figure 2. American Sign Language production of a singular of **SOMEONE/SOMETHING** (an upward pointing index finger produced with a small circular motion).

Context: The speaker is talking about needing a mechanic for his old car.

Sentence: IX-$_{\text{1st person}}$ SURE CAN FIND SOMEONE$_{\text{(low/high)}}$
I'm sure I can find someone (*of the mechanics I know: low –2a)/ (of all mechanics: high –2b)*.



2a. "Someone" SOMEONE$_{\text{LOW}}$ (of smaller set)

2b. "Someone" SOMEONE$_{\text{HIGH}}$ (of larger set)

Figure 3. American Sign Language production of the negative quantifier **NO-ONE/NOTHING** (a laterally spreading sign using two "O" hands).

Context: The speaker is talking about being the only deaf person in her family.

Sentence: MY FAMILY NO-ONE$_{\text{(high/low)}}$ DEAF, ONLY-ME
'No one (*of my immediate family: low –3a)/ (of my extended family or ancestors: high – 3b)* is deaf, I'm the only one.'

3a. "No one" NO-ONE$_{\text{LOW}}$ (of smaller set)

3b. "No one" NO-ONE$_{\text{LOW}}$ (of larger set)

In their original work on quantifier domain restriction in ASL, Davidson and Gagne suggested it is possible that a gestural origin motivated this current form of domain restriction, based on other work in the grammaticalization of gesture in sign languages

(e.g., Coppola, 2007, Coppola & Senghas, 2010; Hendriks, 2009; McClave, 2001; So, Coppola, Licciardello, & Goldin-Meadow, 2005; Wilcox, 2004). This is particularly the case because the vertical axis is used in ASL to provide *subset/superset* information about quantifier domains (Davidson & Gagne 2014), and it is already known that English speakers have a MORE IS UP metaphor (Lakoff and Johnson 1980, Winter et al. 2013, Langston 2002, Sell and Kaschak 2012), so it seems likely that one could have been a grammaticized link from the other. However, it's important to note that the use of UP/the vertical axis for a set/subset relationship like that found in ASL goes beyond the simple matching of a number line with an axis that has been investigated before, and what to our knowledge has been the extent of experimental study of spatial/number metaphors across gesture and sign.

Current study

The current study serves three purposes. First, we investigate whether English speakers, who are known to make use of the metaphor MORE IS UP in their gestures for numerosities (like temperature, prices, etc.), will extend this metaphor to a more abstract type of ordering, between sets and supersets, as occurs in ASL. The second purpose is to contribute to a growing body of research (e.g., Senghas, Kita, & Özyürek, 2004) investigating the origins of and processes by which many mature sign languages have adopted and grammaticized the gestures of the hearing community around them. Specifically, we examine the grammaticalization of gestures of English speaking non-signers in the United States into ASL. We hypothesize that where signers of ASL have separated the horizontal and vertical axes to convey set size information in similar, yet different ways (Davidson &

Gagne, 2014a, 2014b), speakers of English may conflate the two axes frequently in their gesture by producing gestures that change on both axes simultaneously (e.g., a higher and wider gesture). If so, this would provide evidence that the use of the vertical axis to convey set size in ASL has roots in the gesture productions of hearing non-signers. However, it would suggest that its gestural form is not grammaticized, or as limited in application and interpretation, as it is in ASL. Relatedly, the third purpose is to investigate differences between (i) speech-supported gesture and (ii) pantomime (without speech) in English speakers and compare both to signers of ASL in order to further understand how both speech and gesture contribute information in areas of semantic/pragmatic reasoning like quantifier domain restriction.

Methods

Participants

Our sample of participants consisted of 4 (3 females, 1 male) native speakers of English. No participant had any prior experience with ASL. All participants were undergraduate students at Yale University who were compensated $15 for their time.

Procedure

Participants worked individually with two experimenters. First, participants were asked to read a series of short stories or statements (prompts), which each employed one type of quantifier (Table 1). The quantifier of interest appeared 1-6 times within each prompt. Within each prompt, 1-6 sets representing domains of varying sizes were referenced. While Experimenter 2 was out of the room, participants read each prompt, and were asked

to repeat the story back to Experimenter 1 in English without looking at the prompt, in order to ensure the participant had learned the content of the prompt, with the instruction that participants need not repeat the story word for word. If participants' responses differed too greatly from the prompt, participants had an opportunity to read the prompt again and repeat it to Experimenter 1. No participant needed to reread a prompt more than once.

After Experimenter 2 was invited back into the room, participants were instructed to explain to Experimenter 2 the prompt they had just reviewed with Experimenter 1, this time only using their hands – specifically, "without using words" (pantomime phase). Participants were told that after their non-verbal retelling, Experimenter 2 would try to guess what the participant had pantomimed. After Experimenter 2 guessed, participants were instructed to retell the story, this time using "hands or words in whatever combination felt natural," (co-speech gesture phase). This process was repeated for 13 prompts (8 stimuli, 5 fillers). The order of the prompts was initially randomized, and then the order of the list was reversed for half (2) of the participants. Six example prompts, three long and three short, can be found in Table 1.

Prompts were selected based on what was most effective in elicitations in previous studies with ASL participants (Davidson & Gagne, 2014a, 2014b), using contexts that would be most pragmatically felicitous for the expression of set size (i.e., contexts which had potentially very wide domains, such as illness, lottery, or the internet). While the original elicitations Davidson & Gagne (2014a, 2014b) used were not intended to discuss multiple (more than 2) comparison sets within the same utterance, the current stimuli also included

multiple sets (e.g., everyone in the suite, then college, then city, and so on), creating a natural contrast to aid participants' gesture production of set sizes. Prompts varied in length and participants were provided opportunity for recall in order to reduce any memory load which would interfere with their gesture production.

Table 1. Example long (1) and short (2) prompts.

Quantifier		**Prompt**
Everyone	1	There's a zombie attack at Yale. First everyone in your suite becomes zombies. Then everyone in your college becomes a zombie. Then you hear that everyone at Yale has become a zombie. Then everyone in New Haven becomes a zombie. Then everyone in the US becomes a zombie. Suddenly, everyone in the world has become a zombie.
	2	The flu is bad this year. Everyone got sick – including my family.
Someone	1	There's a lottery at school. Someone in every suite is going to win a shirt. Someone in every college is going to win a bag. Someone at Yale is going to win money.
	2	I saw on Facebook that someone – I don't know who – made a video about the swim team.
Nothing/ No-one	1	I was trying to open an assignment for a class on my computer when I realized that there was nothing left in my folder for the class. Then I realized that there was nothing left in my folder for the whole semester. Then I realized that there was nothing left in my entire documents folder. Then I realized there was nothing left at all on the computer. Oh no!
	2	I played my mom in cards yesterday. In ten years, no one has ever beaten her at cards.

Coding

For the purposes of the current analysis, only participants' gestures and pantomimes referring to set size were coded. In ASL, it is not absolute height that matters for set sizes, but only relative height; therefore, a gesture or pantomime was not coded for absolute height, but rather as change in the vertical or horizontal axis relative to the participant's most recent gesture or pantomime describing set size (Figures 4 - 7). The highest (vertical axis) and widest (horizontal axis) portion of the gesture was always coded. Gestures and pantomimes were coded by viewing freeze-frames of relevant portions of the video, then comparing the location of each pantomime or gesture that was described.

Figure 4: Non-signing gesturers use *vertical* along with horizontal axis to express set size. For example, this is one gesturer's production of the inclusive "*everyone*" during pantomime:

Prompt: **"***I* bought a lottery ticket. It turns out there was a fluke in the system, and *everyone* who bought a lottery ticket won!"

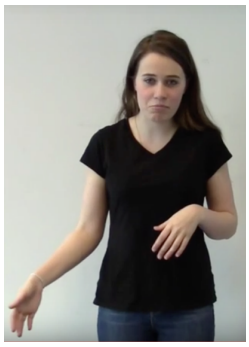
4a. "I" via a point to self, indicating a small set of 1.

4b. "Everyone" (larger set). This participant used height (vertical axis) along with width (horizontal axis) to indicate the set size.

Figure 5: Another example of the use of the vertical axis to indicate set size, this is one gesturer's production of a set size *decrease*:

Prompt: "The flu is bad this year. Everyone got sick -- including my family."

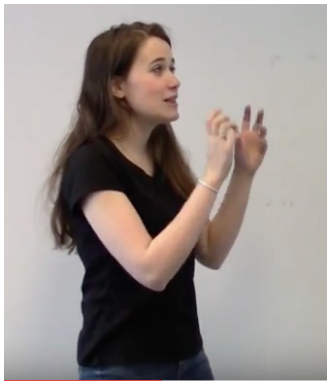
5a. "*Everyone* got sick…"



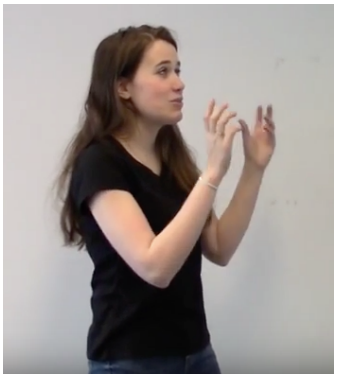
5b. "including *my family"*

Figure 6: Non-signing gesturers can use a single axis to express set size. This is one gesturer's production of *nothing* during co-speech gesture using only the *horizontal axis*:

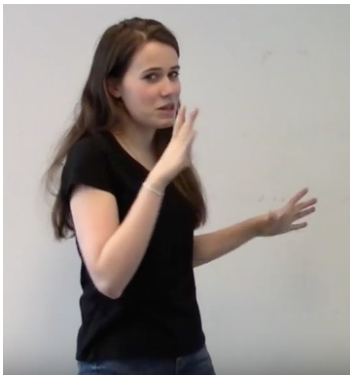
Prompt: "I was trying to open an assignment for a class on my computer when I realized that there was *nothing* left in my folder for the class. Then I realized that there was *nothing* left in my folder for the whole semester. Then I realized that there was *nothing* left in my entire documents folder. Then I realized there was *nothing* left at all on the computer. Oh no!"



6a. "…when I clicked on the folder for class *there was nothing inside*."



6b. "Then I clicked on my documents folder *there was nothing inside*."



6c. "Then I looked at my whole computer and *there was nothing* on my entire computer."

Results

Various strategies

All participants used both vertical and horizontal gestures for set sizes to some degree in either co-speech gesture or pantomime conditions (e.g., Figures 4-6), showing a slight preference for vertical indicators particularly in the pantomime conditions (Tables 2 & 3). Three participants showed horizontal and vertical indicators equally, but only in the co-speech condition (Table 3). While all participants used both axes at some point in the task, they did not always use them simultaneously. For example, in the co-speech condition, participant 1 used the vertical axis only for prompt number 5, the horizontal only for prompts number 7 and 8, and both for prompts 1 through 4 (Table 5).

Expression of set size in gesture vs. pantomime

Three of our four participants (1, 2 and 4) preferred to indicate set size in their (no speech) pantomime more than in their (co-speech) gesture, with their average number of strategies per item decreasing greatly from pantomime to gesture (Tables 2 & 3). Two participants (2 and 3) consistently gestured relatively equally for set size both in pantomime and co-speech gesture. Interestingly, co-speech gesture did elicit slightly more gesture for participant 3 than pantomime did, in spite of our assumption that pantomime would elicit more gestures due to limiting the information available via speech.

Table 2: Total number of gestures referencing set sizes in pantomime (gesture without speech).

Participant #	Horizontal	Vertical	Total	Ratio Horizontal/ Vertical	Average # strategies per item
1	22	24	46	.92	5.75
2	8	11	19	.73	2.38
3	10	12	22	.83	2.75
4	7	8	15	.88	1.88

Table 3: Total number of gestures to indicate set sizes in co-speech gesture.

Participant #	Horizontal	Vertical	Total	Ratio Horizontal/ Vertical	Average # strategies per item
1	10	10	20	1.00	2.50
2	7	9	16	.78	2.00
3	13	13	26	1.00	3.25
4	2	2	4	1.00	0.50

Table 4. Vertical and horizontal axis strategies per participant in pantomime (gesture without speech).

Participant #	**Axis**	**Prompt # 1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
1	Horizontal	X	X	X	X	X		X	X
	Vertical	X	X	X	X	X		X	X
2	Horizontal	X	X	X	X			X	
	Vertical	X	X	X	X			X	
3	Horizontal	X	X		X	X		X	
	Vertical	X	X		X	X		X	X
4	Horizontal			X	X			X	X
	Vertical			X	X		X	X	X

Table 5. Vertical and horizontal axis strategies per item and participant for co-speech gesture.

Participant #	Axis	Prompt #1	2	3	4	5	6	7	8
1	Horizontal	X	X	X	X			X	X
	Vertical	X	X	X	X	X			
2	Horizontal		X	X	X			X	
	Vertical		X	X	X			X	
3	Horizontal	X	X	X	X	X		X	
	Vertical	X	X	X	X	X		X	
4	Horizontal		X						
	Vertical		X	X					

Vertical space is not used for separate sets of (possibly) different sizes

It is of note that, just as for ASL, in gesturers the vertical axis is reserved for indicating set sizes and/or set size changes among sets with subset/superset relationships. That is to say, the vertical axis is not used to indicate the relative *numerosities of different sets* in a referential context that do not have subset/superset relationships. To underscore this point, we look to gesturer productions for a prompt with two sets that are not in a subset/superset relationship:

> "I have two twin brothers. Everyday this week, my one twin brother and his friends played soccer against my other twin brother and his friends. Some days, my one brother's team did better. Some days, my other brother's did better. Everyday, no matter who did better, afterward everyone would go out for a drink."

This prompt, included as a comparison prompt, elicited data that further supports our hypothesis. Even participants who previously favored the vertical axis (e.g., participant 2), did not use the vertical axis to discuss one brother's team over the other or even to introduce *everyone*. We hypothesize that this is because the pragmatic interpretation of *everyone* includes only those previously mentioned – people on one team or the other, but

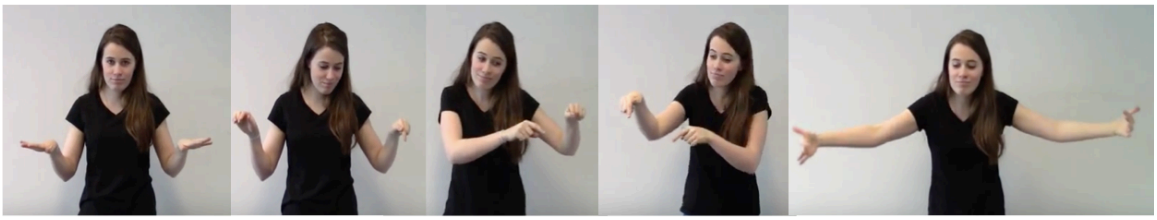
no one new (e.g., not including the speaker, friends of the team members, etc.), so the horizontal axis is sufficient (Table 6, Figure 7).

Table 6: Participant axis use in the twin soccer team prompt. There is a marked preference for use of the horizontal axis to discuss the two teams, even when the quantifier *everyone* is included and would include a sum of individuals larger than either single team alone. The common pragmatic interpretation is that *everyone* need not be marked as a new superset, since it does not necessarily include any more people than previously stated (i.e., players from the two teams).

Participant #	Axis	Pantomime	Co-Speech Gesture
1	Horizontal	X	X
	Vertical		
2	Horizontal	X	
	Vertical		
3	Horizontal	X	
	Vertical		
4	Horizontal	X	
	Vertical	X	X

Figure 7: Non-signing gesturers rarely use the vertical axis when no subset/superset relationship exists. This is one gesturer's production of the twin brothers' soccer team prompt (repeated here):

> **Prompt:** "I have 2 twin brothers (10a). Everyday this week, my one twin brother and his friends played soccer against my other twin brother and his friends (10b). Some days, my one brother's team (10c) did better. Some days, my other brother's (10d) did better. Everyday, no matter who better, afterward everyone (10e) would go out for a drink."



10a 10b 10c 10d 10e

The fact that gesturers universally used the horizontal axis in the pantomime condition and minimally used the vertical axis (only participant 4) lends support to our claim that the vertical axis, even for gesturers, communicates relative set size changes for sets with *subset/superset* relationships as opposed to relative numerosities without subset/superset relationships.

Discussion

In this study, we aimed to test whether the vertical axis would be employed by hearing participants with no knowledge of sign language to indicate set size increases or decreases, particularly because American Sign Language employs the vertical axis for this purpose. Our results support the hypothesis that English speaking non-signers possess the intuition that MORE IS UP not just with regard to mapping the vertical axis onto a single number line (e.g. a *rising* stock price or *lowering* temperature) (Winter et al., 2013), but also apply an abstract subset-superset relationship to locations on this axis, much like ASL does, to the exclusion of sets that do not have this subset-superset relationship. Given that changes in vertical space for corresponding set sizes were demonstrated by every participant of this study, the intuition seems to be robust across multiple English speakers.

Unsurprisingly, vertical axis changes (and thus MORE IS UP) was not the only indicator of set size in our results – participants equally chose to indicate set size changes using height, width or height and width. This, however, does not disprove our hypothesis that the availability of the MORE IS UP metaphor in hearing gesture likely formed the substrate for vertical axis quantifier and verb domain restriction in ASL. ASL employs signing space in a variety of ways, and particularly employs the horizontal axis for various uses, such as anaphoric reference (pronominalization), set comparison, as well as for locative information (see e.g., Sandler & Lillo-Martin, 2006). This likely restricted the grammaticalization of width for domain restriction beyond comparative discourse (i.e., explicit set increases or decreases (Davidson & Gagne, 2014a, 2014b)). It seems natural,

then, that, given the availability of the vertical metaphor MORE IS UP in the gestures produced by hearing individuals communicating with deaf signers, that the vertical axis would become a likely candidate for grammaticalization to indicate quantifier and verb domain restriction in ASL. This is particularly underscored by the productions of ASL informants (Davidson & Gagne, 2014a, 2014b), whose productions do not change in width, but do change in height (Figures 1-3). This is regardless of the absolute sizes of the sets in question, which range from a handful of people (e.g., "my immediate family," e.g., Figure 3) to everyone in the world (e.g., Figure 1) – a strikingly larger set.

While this grammaticalization process for ASL likely occurred quite some time ago, rendering real-time observations of language change unlikely, examples of a similar process of grammaticalization, where gestures were deconstructed into contributing elements (such as height vs. width in the current study), has recently been observed in newly emerging sign languages such as Nicaraguan Sign Language (NSL). Senghas, Kita, & Özyürek (2004) observed that Nicaraguan hearing non-signers' gestures indicating motion events conflated path and manner information into a single gesture describing the event (e.g., "roll" and "down" simultaneously). Signers of the newly-emerged NSL, however, described the same events using discrete, sequential elements (e.g., "roll," then "down"), in spite of the fact that in the initial stimuli video these elements actually occurred simultaneously (e.g., a cartoon cat rolling down a hill). It appears that initially simultaneous gestures were broken down into discrete combinatorial elements which were then grammaticized much like the combinatorial elements found in all languages (i.e., phonemes, morphemes, lexical items, etc.). This process of grammaticalization may explain, for example, why many of our gesturers were not

consistent in using height and/or width for their set size changes. As described by Senghas et al. (2004), iconic gestures represent continuous productions with no grammatical constraint or production requirements whereas signs using the same elements must adhere to grammatical rules and related semantic information. In an example using vertical height, an ASL quantifier ALL produced high in vertical space *cannot* refer only to a small set, such as one's immediate family or friend group – this would be ungrammatical in ASL (Davidson & Gagne, 2014a, 2014b), while in gesture this may be more flexible.

Broadly, our study suggests that English speakers engage with the metaphor MORE IS UP when attempting to communicate not just information on number lines but also subset/superset relationships. This metaphor is available robustly, across all our participants, although it was not employed consistently across all participants for the same items. This raises the question as to why English speakers have not yet grammaticized gesture to describe an increase in set size to the same extent as in ASL, even in instances in which the referent of the quantifier (e.g. *everyone* in "everyone came to an agreement") is ambiguous, and a grammaticized gesture could well be informative in discourse. In such instances, however, non-signers have alternative options and may compensate with intonational emphasis while signers use the vertical axis for the same purposes. This could explain why distinguishing this subset/superset relationship has become a part of the grammar of ASL, but is most often absent from co-speech gesture of non-signers outside of specific settings like that in our study. More research should clearly be done on the relationship between rises and lowers in intonation in English

speech and the raising and lowering of sign and gesture height evidenced in the study we present here.

Finally, cross-cultural studies are needed in order to determine if a similar intuition that MORE IS UP for set size is present in other signed languages, in non-English speakers, and in non-Western non-signers. Performing cross-cultural experiments could support either the hypothesis that it is a culturally based extension of a metaphor, or that it is a non-arbitrary one accessible to users from multiple, or possibly all, cultural and linguistic backgrounds.

The current paper aimed to investigate an extension of a well-known metaphor for English speakers, MORE IS UP, beyond simply the number line to capture subset/superset relationships. We showed for the first time that English speakers have access to this use of vertical height for conveying set information, along with a similar use of width to also convey the subset/superset relationship. In light of new findings that American Sign Language uses height to convey this information, our results are highly suggestive that the ASL use of height has a gestural origin in the larger cultural community in the United States. Moreover, we can see pieces of the process of grammaticalization, with more regularized use in ASL but more variable use in both pantomime (no speech) and co-speech gesture, consistent with previous studies of grammaticalization processes from gestures to sign. We hope that future research involving cross-cultural studies will shed light on how variable such uses of height and width are across cultures for conveying subset/superset relationships, and in return inform our understanding of the relationship between speech, sign, and gesture.

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