TOPIC-OPENENDEDNESS:
WHY RECURSION IS OVERRATED

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Humans can use language to refer to and describe endless varieties of situations, thoughts, ideas, and topics, including hypothetical situations and events that never happened. This capacity, referred to here as *topic-openendedness*, is a key feature distinguishing human languages from animal communication systems and any theory of language and language evolution should account for it. Recursion, the mechanism that provides language with the capacity for discrete infinity, can account for the fact that languages can create an infinite number of sentences from a finite set of words and rules. But it *cannot* account for the openendedness of the *contents* of those sentences. Therefore, the importance attributed to recursion as the *sole* mechanism that is *uniquely human* is overrated. We suggested that a key factor in explaining topic-openendedness is the nature of the linguistic symbols, the words, specifically their ability to extend their meanings beyond their basic meaning, to other, novel semantic domains, by means of cognitive processes such as metonymy and metaphor. Meaning extensions allow language users to apply a finite lexicon to an infinite number of situations and topics, and play a crucial role in explaining topic-openendedness.

1. What is special about human language: Topic-openendedness

In the past few decades, recursion has come to be regarded as one of the most fundamental properties of human languages and the human capacity for language. In Hauser et al. (2002) it was upgraded to the sole feature of FLN, the faculty of language in the narrow sense, which, according to the authors, consists of those features that are exclusively characteristic of human language, not shared by other human cognitive abilities or by other species. The reason for the importance attributed to recursion is that it is regarded as the property responsible for the

openendedness of human language, its capacity for 'discrete infinity', which distinguishes human language from animal communication systems (henceforth, ACSs).

However, discrete infinity, the ability to create an infinite number of sentences from a finite set of words and rules, is but one of the facets of language's openendedness, and, we argue here, not the most important one. The importance of the openendedness of human language lies not only in its ability to create an infinite *number* of sentences, but also in what we can *convey* with these sentences. Language allows its users to refer to endless varieties of situations, thoughts, ideas, and topics. By using language, we can refer to and describe any topic that we feel a need to express, situations that are detached from the here-and-now (allowing for *displacement*, c.f. Hockett, 1960), hypothetical situations, situations that will not or cannot take place, and novel situations. *We can always use language to relate to new situations*. This ability, called here *topic-openendedness*, stands in marked contrast to ACSs, that express information revolving around survival: food and feeding, predator-prey relations, mating and reproduction, and signaling social hierarchies (Hauser, 1996).

The paper makes several novel points. First, I argue that the uniqueness of human language lies in topic-openendedness as much as in discrete infinity. Recursion does not facilitate topic-openendedness, and therefore we should shift our focus of investigation and try to find factors that do contribute to it. Second, I suggest that a key factor in explaining topic-openendedness is the special nature of linguistic symbols, the words, especially their ability to take on meaning extensions by means of processes such as metonymy and metaphor. Though meaning extensions have been studied thoroughly in the semantic literature, their important role in facilitating topic-openendedness has not been previously acknowledged. I present three arguments to support these claims: (1) A thought experiment showing that recursion cannot account for topic-openendedness, but that meaning extensions can (section 2); (2) Evidence showing that recursion is not necessary to account for the openendedness of language, as languages can do without a syntactic mechanism for recursion and still express recursive thoughts (section 3); (3) Evidence from young languages showing that syntactic recursion is not found in early stages of a language, but even in its very early stages, a language can refer to novel and displaced situations, distinguishing it from ACSs (section 4). The concluding section (5) suggests a few factors that contribute to topic-openendedness, and should become the focus of future studies.

2. Topic-openendedness: the role of meaning extensions

All languages are characterized by topic-openendedness. Which factors contribute to this special ability? I propose that a central factor is the flexibility of the symbols that make up language, the words. Our ability to create and use symbols is at the heart of our special linguistic ability (Deacon, 1997, Bickerton, 2009). Words, vocal or gestural (manual) signals that are associated with (or represent) a *concept* (Pinker and Jackendoff, 2005), are crucial for using language to refer to entities of various kinds (humans, animals, objects), actions, states, emotions, abstract concepts and more. The ability to create new words, employed constantly and incessantly by language users, is the basis for our capacity to apply language to novel situations. Yet even a very large lexicon is finite at any given point in time and for any given individual, while the number of types of situations, entities and concepts we want to refer to is infinite. What happens when we encounter a situation which we have no words for? We can create new words, and we often do. But more often, we extend the meanings of the words we have to cover those new needs. So, interestingly, though the meaning of words is precise (a property which Hockett, 1960, refers to as 'semanticity' and lists as one of the design features of human languages), it is not altogether fixed. *It is this flexibility that underlies our ability to refer to novel entities and situations.*

I demonstrate the power of this flexibility through a thought experiment. Consider two languages, L_A and L_B. The two have almost identical vocabularies (very limited) and the same sentence structures. They differ in the following: only L_A has a recursive mechanism; it can embed a constituent within the same kind of constituent (in the example here, by means of a complementizer, but other means are possible too, of course), creating embedded structures of potentially infinite length. In addition, each word has precisely one meaning; neither polysemy nor any other meaning extensions is possible. L_B does not have a mechanism for recursion. However, it allows for polysemy, specifically metonymy and metaphor. Crucially, both languages are compositional and generative: both have the ability to combine words to create larger units, such as phrases and sentences.

Table 1. Vocabulary of both languages

nouns	verbs	adjectives	prepositions	COMP
man, woman, dog, head, house, sky, water, apple	eat, run, say, write walk	small, white, big	in, after, to	that (only in L_A)

Here are some situations that both languages can refer to: (1) *The man/woman/dog ate an apple.* (2) *The man/woman/dog run after the man/woman/dog– run in the house – run to the house/apple/man/woman/dog/water.* (3) *The*

woman/man/dog/house/apple is big/small/white. (4) *The big/small/white woman/man/dog run/eat/read/write etc.* In addition, L_A can produce embedded structures such as: (5) *The woman/man said to the man/woman that …*(any of the above sentences). (6) *The woman said that the man said that the woman said that* … (any of the above). So, formally, L_A is infinite: it can produce an infinite number of sentences. L_B, lacking the mechanism of recursion, cannot do that.

However, let's consider a situation where speakers of each of the languages want to refer to an animal other than a dog, say, a cat or a donkey. L_A does not provide its speakers with means of doing it, since it avoids polysemy or meaning shifts. L_B speakers, on the other hand, can use the word *dog* to refer to other animals as well, simply by extending its denotation, as small children often do. They can also create compounds such as *small-dog* for 'cat' and *big-dog* for 'donkey'. L_A speakers can also create combinations like *small dog* and *big dog*, but they can only mean a small or a big dog respectively, since the word *dog* cannot be extended to other animals. L_B speakers can also create compounds like *sky-dog* and *water-dog* for 'a bird' and 'a fish' (or any other water animal) respectively. Similarly, the meaning of *apple* can be extended to other fruits and vegetables; the meaning of *head* can be extended to denote 'the top part of X', and then the spatial relation 'on'. So speakers of L_B can say *dog head house*, meaning 'the dog is on the house'. They can create new verbs such as *head-say* for 'think', *water-eat* for 'drink', and new adjectives such as *head-big* 'smart', *head-small* 'stupid'. If they want to refer to something new, or clean, they can use the word *white* to refer to all three properties – white, new and clean. They can also use *white-sky* for 'clouds', *white-water* for 'alcoholic/intoxicating beverage', *white-dog* for 'a sheep', and *white-say* to 'saying good things, praising'.

All these semantic shifts that L_B uses are very familiar. Languages use meaning extensions, such as metonymy and metaphor, to refer to new situations. There is nothing new in these examples. In fact, they are quite trivial; we are so used to them that they have escaped our radar when we try to explain what is so special about language. But the point is that these processes play a central role in our ability to use language to convey a novel concept or situation -- *any* concept or situation. Therefore, although L_A is infinite in the mathematical sense, it is rather limited when it comes to referring to new situations. L_B may be finite from a mathematical point of view, yet it is so much richer than L_A in terms of its expressive capabilities; it is not limited by its vocabulary to specific topics. The comparison between these two artificial languages shows that even with a very limited vocabulary, a communication system (L_B) can exhibit topic-openendedness, making it much more language-like than ACS-like. Without the capability for topic-openendedness, a communication system (L_A) is much less language-like, even if it mathematically infinite.

3. Expressing recursive thoughts: is syntactic recursion necessary?

Meaning extensions, and not recursion, can explain how we use a finite vocabulary to refer to an infinite number of situations and thoughts. Yet maybe there are types of thoughts that can only be expressed by a recursive mechanism. For example, is recursion necessary for expressing complex, recursive thoughts, that is, propositions embedded in other propositions, another aspect of the infiniteness of language? It turns out that this is not the case. Recursive thoughts can be expressed by parataxis, putting one utterance after another, rather than by syntactic recursion or embedding. Evans and Levinson (2007, 443) show that content conveyed by an embedded structure (e.g. a conditional clause), can also be conveyed by non-embedded syntactic structures: "Consider that instead of saying, "If you move, he'll shoot", we could say: "You move and he'll shoot." In the former case we have syntactic embedding. In the latter the same message is conveyed, but the "embedding" is in the discourse understanding – the semantics and the pragmatics, not the syntax.

Similarly, in Al-Sayyid Bedouin Sign Language (ABSL), a village sign language of Israel that emerged in the Al-Sayyid community in the early 30s of the 20th century (Sandler et al. 2005, Meir et al. 2010), reported speech, another instance of recursive thoughts, is conveyed by several means, none of which involves syntactic recursion. One way is to cite the content of the speech, without explicitly indicating who said it. In a narrative told by a first generation signer of ABSL, he signs the following dialogue: - GUN GIVE-ME 'Give me the gun'; - SWEAR (BY-)GOD, NO 'I swear by God's name, no!' (Sandler, 2012). The signer does not embed the reported content in another clause. The fact that these utterances are instances of reported speech is indicated by his body posture and by the general context and shared background. There is no syntactic mechanism involved here, yet the semantic function of reported speech is conveyed.

Another way of expressing reported speech is by mentioning the speaker, and the content of the speech: FATHER: NO, STAY HOME 'Father [said]: no, you stay home'. Again, there is no syntactic embedding, as there is only one clause, and a noun preceding it. The embedding is clearly in the semantics or pragmatics. Everett (2012;196) mentions precisely the same mechanism for reporting speech in Wari', an Amazonian language.

A third generation ABSL signer uses the sign SAY to introduce reported speech. This mechanism is very similar to direct speech in English. FATHER SAY: WHY YOU LONG-TIME SEE NONE WHY? 'Your father said: "why haven't we seen you for such a long time, why?"'

In all three cases, the signer expresses recursive thoughts, the embedding of one proposition (the content of the saying) in another (the saying event). But none of the ABSL mechanisms encodes syntactically the recursive nature of these propositions. These data, and the data presented in Evans and Levinson (2007),

provide evidence that syntactic recursion is not necessary for expressing recursive thoughts or messages (Jackendoff, 2011; see also Gil 2009 for Indonesian/Malay).

Furthermore, in many languages it is not clear that recursion leads to discrete infinity. In some languages, e.g., Kayardild (Evans & Levinson 2007, 442), recursion is limited to one cycle of application. Other languages use embedded structures very rarely, e.g. polysynthetic languages, in which the complexity resides in the morphology rather than in the syntax (see Evans, 2003; Mithun, 1984 for specific languages). Finally, even in languages where recursive structures are very common (e.g. English), center embedding beyond two levels is almost non-existent, and tail embedding usually does not exceed three or more levels in actual language use (Heine and Kuteva 2007, 297). Taking all the evidence provided in this section together, we conclude that recursion cannot carry the burden of accounting for the openendedness of human language.

4. The diachronic perspective: the view from young languages

We turn back to what we claim here is the central aspect of the openendedness of language, topic-openendedness. Further evidence for its centrality comes from novel and very young languages. Studies of such communication systems show that even at very early stages of their emergence, languages exhibit topic-openendedness. Even homesign systems, gestural communication systems invented by deaf children with no exposure to a conventional sign language, can do this (Goldin-Meadow 2003, 2005). The literature of pidgins and creoles provides abundant examples that show displacement (see e.g., Holm 1989). Studies of early stages of young sign languages in Israel show that 1st and 2nd generation signers tell stories of the history of their community, talk about diverse topics such as folk remedies, social security rights and health issues, and plan future actions and events (Sandler et al. 2005, Kastner et al. 2014, Meir et al. 2016. See also Ergin 2017 for Central Taurus Sign Language in Turkey).

These languages are often described as having very little syntax, and no mechanism for syntactic embedding. Other studies show that markers of embedding may develop over time. In some cases, embedding is marked by prosodic cues, e.g., a special facial expression and a forward body posture (see Sandler et al., 2011, for the development of systematicity in the prosodic marking in ABSL), or by means of shortening, both in time and in space, the movement of the predicate to mark it as secondary (dependent) to the main predicate in KQSL (Kastner et al., 2014). Similar findings are reported about Nicaraguan Sign Language (Senghas et al., 2016).

In other cases, overt markers of subordination can develop over time as well. Dachkovsky traced the development of relative clauses in three generations of ISL signers. The first generation did not have a consistent way of marking relative

clauses. The second generation marked relative clauses by a specific facial expression interpreted as intonational – eye squint (Dachkovsky 2018). In the third generation, a pointing sign, usually used as a demonstrative pronoun, developed into a syntactic marker of relative clause boundaries (Dachkovsky 2016). Similar developments of embedded structures have been reported for many spoken languages (Heine & Kuteva, 2007, ch. 5).

The main point here is that syntactic marking of subordination often develops over time in languages. Languages often have a 'non-subordination' stage in their history, developing the means for overtly marking subordination over time, by means of grammaticalization (which involves phonetic, semantic and morpho-syntactic changes). Yet no language that I know of was reported as having a stage of 'topic-finiteness', that is, a stage in which the language users were confined to a closed set of topics. And it is this characteristic that makes it distinct from ACSs -- that makes it language. In other words, a language without recursion is still a language, whereas a language without topic-openendedness is not.

5. Topic-openendedness: symbols, meaning extensions and compositionality

So far I have established the claim that what makes a communication system a language is first and foremost topic-openendedness, and if we want to understand language we should try to account for that rather than for the ability for discrete infinity, which, as we saw, some languages may do without. From an evolutionary perspective, we have to explain how the capacity for topic-openendedness evolved.

I cannot make any specific suggestions to solve this mystery, and I know of no satisfactory suggested scenarios in the literature. What I would like to do here is to suggest some possible directions for exploration, by bringing to the forefront several properties that I believe enable topic-openendedness. If we can trace the evolution of any of these properties, we would make a great leap forward.

I suggest that two sets of properties are involved in this feat: the nature of the symbols and compositionality. The first has been the focus here; the second will only be mentioned briefly.

Humans have the capacity to create symbols, even without exposure to conventional symbols. This is evident in homesign systems, where deaf children invent signs that were not used by their caregivers (Goldin-Meadow, 2003), and by young sign languages, whose developing vocabulary is a testimony to this capacity (Meir et al., 2016). In the manual-visual modality, many of these signs are iconic; humans, unlike other primates, have the capacity to create iconic symbols (Sandler, 2009, 253). Humans may use iconic signs to refer to abstract notions by means of metonymy – iconically depicting an object, entity or action related to the abstract concept (e.g. wheat harvesting for 'year', and a handshake

for 'holiday' in ABSL). In addition, humans extend the meanings of the words in their lexicons to refer to and express novel situations, by means of metonymy and metaphor. For example, in a narrative of a first-generation ABSL signer, he uses the signs for SWORD, GUN, CUCUMBER metonymically, to refer to people: the man with the sword, the man with the gun, and the man that grows cucumbers. Metaphorical extensions are also evident in the creation of signs (see Taub, 2001, for an extensive analysis of metaphors in sign languages) and in creating meaning extensions, such as using the sign THIRSTY to mean 'want' in Algerian Jewish Sign Language (Meir et al., 2016).

Spoken languages are not different from sign languages in this respect. They also extend the use of their words to novel entities and situations. Any glance at any item in a dictionary would make this point. There are hardly any items that have only one sense. Even a grammatical word such as *the* has four senses or functions, with several sub-functions in each (Meriam-Webster online dictionary)[1]; the word *cat* has seven senses, and the word *run* has over 50 senses or meanings. The exact number of senses or meanings may be hard (or even impossible) to determine, but this is precisely the point: we use our finite set of words in novel and creative ways to refer to an infinite number of concepts and situations. This is a different facet of von Humboldt's famous saying that language "makes infinite use of finite means".

It is not clear how the ability for meaning extension developed in the course of language evolution. The study of ape gestures might be a possible starting point. It has been suggested that ape gestures show greater flexibility than facial expressions and vocalizations in terms of the behavioral contexts they occur in, and therefore the interpretation of gestures need to take into consideration a larger combinatorial context (Pollick and de Vall, 2007). Furthermore, ape gestures may show the buds of metonymy. When an ape scratches his body in a particular way to request to be scratched at this spot, the directed scratch is associated with the intended action by metonymy: it represents the entire event of scratching, including an agent different from the communicator (Pika and Mitani 2009; see also Hobaiter and Byrne 2014 for a large inventory of meaningful gestures in chimpanzees). These gestures are instructions for actions rather than referential symbols, but they nonetheless make use of metonymy. Though the path from these gestures to the wide use of meaning extension in human language is still a mystery, at least there is a possible evolutionary precursor to start from (Liebal and Call 2012).

The second set of properties that are needed to account for topic-openendedness is related to the notion of compositionality, our ability to combine symbols to create novel utterances whose meaning can be calculated on the basis of the meanings of their components and the way they are combined (Frege 1892). This

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[1] https://www.merriam-webster.com/dictionary/the

ability is crucial in order to create a system with generative power. A good deal has been written about compositionality, and we limit our brief remarks here to predication and negation.

A specific kind of semantic relation which is based on compositionality is predication, the ability to 'say something about something', to attribute a property, an action or an event to a referent. Bickerton (e.g., 1990, 2009) has acknowledged and emphasized the importance of predication to human language and the evolution of syntax, and tried to suggest possible evolutionary precursors, but these are analogical (e.g. the behavior of foraging ants), and very different qualitatively from what we find in human languages. Others have suggested that predication is a development within homo sapiens, built on neural machinery that underlies other systems, such as CV syllable structure (Carstairs-McCarthy 1999) or the inherent asymmetry between the hands when manipulating tools (Krifka 2008). While the origin of predication is unclear, its significance in language cannot be emphasized enough. Predication is crucial for achieving displacement, since it enables us to separate a protagonist from the event it is performing or undergoing, and to place a situation in time with respect to speech time and therefore to detach events form the here-and-now.

Related to predication is negation. As far as I know, among natural communication systems, only human languages have the ability to negate, to state that something does not exist or did not happen, an important aspect of topic-openendedness. Though ACSs may express related notions such as refusal or forbidding, these are still manipulative in nature and are not used as an assertion.

All the above properties – use of symbols, meaning extensions and compositionality, including predication and negation – are found at the very early stages of languages, enabling them to exhibit topic-openendedness, and setting them apart from other ACSs. If we want to characterize and understand human language and how it evolved, we should address these issues, rather than focus mainly on recursion.

References

Bickerton, D. (1990). *Language and Species*. Chicago & London: The University of Chicago Press.

Bickerton, D. (2009). *Adam's Tongue: How Humans Made Language, How Language Made Humans*. New York: Hill and Wang.

Carstairs-McCarty, A. (1999). *The Origins of Complex Language*. Oxford: Oxford University Press.

Dachkovsky, S. (2016). The development of a Relative Clause marker from a deictic gesture in Israeli Sign Language. Talk presented at *AG 7: Sign*

language agreement revisited: New theoretical and experimental perspectives, Konstanz, February 2016.

Dachkovsky, S. (2018). *Grammaticalization of intonation in Israeli Sign Language: From information structure to relative clause relations.* PhD dissertation, University of Haifa.

Deacon, T. (1997). *The Symbolic Species: The Coevolution of Language and the Brain.* New York: Norton.

Ergin, R. (2017). *Central Taurus Sign Language: A Unique Vantage Point into Language Emergence.* (Ph.D. Ph.D. Thesis), Tufts University. https://search.proquest.com/openview/69f73091abbc97d1d2997408076c530 1/1?pq-origsite=gscholarandcbl=18750anddiss=y

Evans, N. (2003) *Bininj Gun-wok: A Pan-dialectal Grammar of Mayali, Kunwinjku and Kune*. Canberra: Pacific Linguistics.

Everett, D. (2012). *Language: the Cultural Tool*. New York: Pantheon Books.

Frege, G. (1892). On Concept and Object. *Vierteljahrsschrift für wissenschaftliche Philosophie*, 16: 192–205, Peter Geach (trans.), (1952) *Translations from the Philosophical Writings of Gottlob Frege*, Oxford: Blackwell, pp. 42–55.

Gil, D. (2009). How much grammar does it take to sail a boat? In G. Sampson, D. Gil, and P. Trudgill (eds.), *Language Complexity as an Evolving Variable*. Oxford: Oxford University Press, 19-33.

Goldin-Meadow, S. (2003). *The Resilience of Language: What Gesture Creation in Deaf Children Can Tell Us about How All Children Learn Language*. New York: Psychology Press.

Goldin-Meadow, S. (2005). What language creation in the manual modality tells us about the foundations of language. *Linguistic Review*, 2005, *22*, 199-225.

Hauser, M. (1996). *The Evolution of Communication*. Cambridge, MA: MIT Press.

Hauser, M., Chomsky, N. and Fitch, T. (2002). The faculty of language: what is it, who has it, and how did it evolve. *Science* 298, 1569–1579.

Heine, B. and Kuteva, T. (2007). *The Genesis of Grammar: A Reconstruction*. New York: Oxford University Press.

Hobaiter, C. and Byrne, R. W. (2014). The meanings of Chimpanzee gestures. Current Biology 24, 1596–1600, http://dx.doi.org/10.1016/j.cub.2014.05.066

Hockett, C. F. (1960). The origin of speech. *Scientific American*, 203, 88–111.

Holm, J. (1989). *Pidgins and creoles*. Vol II. Camridge: Cambridge university Press.

Jackendoff, R. (2011). What Is the Human Language Faculty? Two Views. *Language*, 87(3) 586-624.

Kastner, I., Meir, I., Sandler, W. and Dachkovsky, S. (2014). The emergence of embedded structure: Insights from Kafr Qasem sign language. *Frontiers in Psychology, 5,* 1-15.

Kocab, A., Senghas, A. and Snedeker, J. (2016). Recursion in Nicaraguan Sign Language. *Proceedings of the annual meeting of the Cognitive Science Society*. https://mindmodeling.org/cogsci2016/papers/0239/index.html

Krifka, Manfred. 2008. Functional similarities between bimanual coordination and topic/comment structure. In: Eckardt, Regine, Gerhard Jäger and Tonjes Veenstra, (eds), *Variation, selection, development. Probing the evolutionary model of language change*. Berlin: Mouton de Gruyter, 307-336.

Liebal, K. and Call, J. (2012). The origins of non-human primates' manual gestures. *Philosophical Transactions of the Royal Society B,* 367(1585): 118–128. doi: 10.1098/rstb.2011.0044

Meir, I., Sandler, W., Padden, C. and Aronoff, M. (2010). Emerging Sign Languages. In: M. Marschark, and P. Spencer (Eds.) *Oxford Handbook of Deaf Studies, Language, and Education*, Vol. 2. Oxford: Oxford University Press, 267-280.

Meir, I., Sandler, W., Ziv Ben-Zeev, Y., Lanesman, S. and Sarsour, M. (2016). How Does a Lexicon Emerge in a New Language? Insights from Village Sign Languages of Israel. *Iyunim be Safa ve-Hevra, 8*(1-2), 11-43. (in Hebrew).

Mithun, M. (1984) How to avoid subordination. *Berkeley Linguistic Society* 10:493–509.

Pika, S. and Mitani, J. C. (2009). The directed scratch: evidence for a referential gesture in chimpanzees? In Botha, Rudolf and Chris Knight (eds.) *The Prehistory of Language*. Oxford: Oxford University Press, 166-180.

Pinker, S. and Jackendoff, R. (2005). The faculty of language: what's special about it? *Cognition* 95, 201–236.

Pollick, A. S. and de Vall, F. B. M. (2007). Ape gesture and language evolution, *Proceedings of the National Academy of Sciences* 104:8184-8189.

Sandler, W., Meir, I., Dachkovsky, S., Padden, C. and Aronoff, M. (2011). The emergence of complexity in prosody and syntax. *Lingua* 121, 2014-2033.

Sandler, W., Meir, I., Padden, C. and Aronoff, M. (2005). The Emergence of grammar: Systematic structure in a new language. *Proceedings of the National Academy of Sciences* 102(7), 2661-2665.

Sandler, Wendy. (2009). Symbiotic symbolization by hand and mouth in sign language. *Semiotica*, 174(1/4), 241-275.

Sandler, Wendy. (2012). Dedicated gestures in the emergence of sign language. *Gesture, 12*(3), 265-307.

Taub, S. (2001). *Language from the Body. Iconicity and Metaphor in American Sign Language*. Cambridge: Cambridge University Press.