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Complex Ideas: Fodor’s Hume Revisited

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To Jerry Fodor (1935–2017), *in memoriam*

1. Introduction

In 2003, Jerry Fodor published *Hume Variations* (*HV*), a book sitting astride *The Mind Doesn’t Work That Way* (Fodor 2000) and *LOT 2* (Fodor 2008). Sadly, we now know that the latter would end up being Fodor’s last solo effort to defend the Representational/Computational Theory of Mind (RCTM) in book format. Thereafter two collaborative endeavors ensued, the widely vituperated *What Darwin Got Wrong* (Fodor & Piattelli-Palmarini 2010) and the sketchy *Minds Without Meanings* (Fodor & Pylyshyn 2015). The former could easily be connected with Fodor (2000) as striking the, in our opinion, definitive blow on evolutionary psychology, while the latter elaborated on Fodor’s (2008) referentialist account of the content of intentional states, hinting, also in our opinion, at the basis of what might eventually constitute a solution for this hard problem—we held our breaths awaiting the next season, only to recently know that it would not be shot. This apparently leaves *HV* in a kind of no man’s land and seemingly makes of it a relatively minor work not worth the attention of the casual follower of the happenings in the philosophy of mind—a text for wholehearted fans only.[1] However, when read as part of a trilogy that opens with Fodor (2000) and culminates with *LOT 2*, *HV* acquires a full sense of its own as the necessary link between the computational model of the former and the theory of ideas developed in the latter. Especially, we believe, when Fodor’s Hume is reassessed under the reading we propose here.

In *HV*, Fodor got it right when he asserted that the etiology of complex ideas is the crux of Hume’s psychology; but he didn’t get it completely right, for Hume’s etiological suggestions are more complex and nuanced than they surface in Fodor’s portrait. The first section of this note is aimed at explaining why we believe so. Thereafter, we move to the question of what, according to Fodor, Hume got inexcusably wrong. Again, while we would like to suggest that Fodor got this partially right, we nonetheless believe that Hume’s contentions are not as inexcusably wrong as Fodor argued them to be, even from the point of view of a

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[1] To wit, we were able to localize only six reviews of the book (Crane 2004, Garvey 2004, Biro 2005, Carruthers 2005, Sarnecki 2005, and Schmidt 2007), while a quick search on Google for *LOT 2*, for example, immediately suggests more than ten hits.

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Cartesian-biased RTCM. Notwithstanding, the conclusion of this contribution is to a great extent in agreement with Fodor's vindication of Hume: Much against conventional wisdom, Hume attained a rather balanced compromise between the constraints imposed by the Cartesian theory of ideas and the rigors of empiricism, which he felt compelled to embrace in order to attain a bona fide scientific view on human nature.

2. Hume on the Etiology of Complex Ideas: What Fodor Got Wrong (or Did He?)

How Hume taxonomized 'perception' into 'impressions' and 'ideas' is a story that has been told many times, obviously enough starting with Hume himself (*Treatise*, § 1.1;[2] see, among others, Stroud 1977: Ch. 2, Pears 1990: Part I, and Garrett 2011). This section is specifically devoted to introducing Fodor's *HV* version of that story and confronting it with our own construal of Hume's relevant passages of the *Treatise*—for those readers wishing to refer to different reviews of Fodor's book for a more all-encompassing set of commentaries, we recommend those of Crane (2004), Garvey (2004), Biro (2005), and Carruthers (2005). Turning then to the case that concerns us here, Hume famously set apart, on the one hand, 'impressions' from 'ideas' as the two main denizens of our perceptual life—which measured against each other by their relative 'force' and 'violence' (Govier 1972, Everson 1988, Dauer 1999, Bennet 2001: 204–206)—and, cutting across both categories, 'simple' from 'complex' impressions/ideas—a matter in this case of internal 'distinctiveness' and 'separability' (Stroud 1977: Ch. 2, Bennet 2001: 209–211, Owen 2009).

As for the former distinction, Hume observed that mental moods exist in which it becomes blurred—like fever, sleep, and so on, but that it is unproblematic in most common situations. He also famously introduced at the beginning of the *Treatise* that there exists a causal arrow pointing from 'impressions' to 'ideas' (*Treatise*, p. 9), so for him it generally rules that:[3]

> all ideas are deriv'd from impressions, and are nothing but copies or representations of them […] Impressions and ideas differ only in their strength and vivacity. (*Treatise*, p. 18)

To this he added that, as a consequence, the distinction is not subservient to "any particular degree of vivacity", as well as the corollary (to be discussed below) that "whatever is true of the one must be acknowledg'd concerning the other" (*Treatise*, p. 18).

As for the latter distinction, Hume introduced it as a clear-cut, uncomplicated one, which has to do with the internal decomposability (or lack thereof) of

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[2] We will quote from the following edition: *A Treatise of Human Nature*, vol. 1, ed. David Fate Norton & Mary J. Norton. Oxford: Clarendon Press, 2007. As for references to Fodor, unless otherwise stated, all are to *HV* with page numbers appearing within parentheses.

[3] As it is well known, in Hume's model ideas feedback to generate new ('of reflection' or 'secondary') impressions (*Treatise*, p. 11). Details are not important to the concerns of this paper and, as Fodor did in his book, we shall omit the mechanism here.

impressions/ideas. The distinction holds the same in the case of both kinds of percepts, which actually follows from the corollary above: Namely, if an impression decomposes into minor impressions, the same property must apply to the corresponding idea—i.e. it must decompose into minor ideas; and obviously enough, simple corresponding impressions and ideas must be equally isomorphous in not being internally decomposable.

But Hume also acknowledged that 'complex ideas' raise a non-trivial challenge to this whole edifice, for

> tho' there is in general a great resemblance betwixt our *complex* impressions and ideas, yet the rule is not universally true, that they are exact copies of each other. (*Treatise*, p. 8; emphasis in original)

Clearly enough, winged horses, fiery dragons, and monstrous giants, are not copies of anything that directly impresses us, in the way ordinary horses, common alligators or basketball players do. Therefore, two different mental mechanisms appear to be at work in the completion of complex ideas, even if both ultimately anchored in the solid ground of impressions. Fodor referred to the corresponding mechanisms as 'copy' (also Bennet 2011: 209ff.) and 'imagination',[4] which superimpose to the 'simple/complex' distinction as depicted in Figure 1:

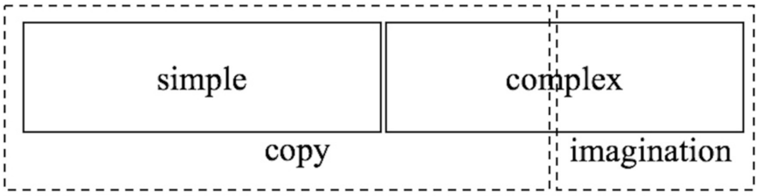

Figure 1: Hume's fabric of ideas (Fodor's version).

According to this reading, 'copy' may apply to create both simple and complex ideas—or 'copies', the difference being that in the former case the mechanism just coins the corresponding idea from a single, non-decomposable impression, while in the latter case it copies a certain number of minor, non-decomposable impressions, plus the 'joints' that keep them apart and, at the

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[4] A note of terminological clarification is in order. Fodor differentiated between 'copy' and 'imagination', understanding the former as the faculty whereby (simple and complex) impressions become (simple and complex) ideas/concepts, and the latter as the faculty that assembles simple ideas/concepts to generate complex ideas/concepts (Fodor 2003, pp. 29–30). But Hume actually opposed 'imagination' to 'memory'—not to 'copy', as the outcome and onset, respectively, of the process whereby impressions progressively faint into ideas (*Treatise*, § 1.1.3): That is, impressions are first (strongly) remembered and then (weakly) imagined. In any event, composing 'unrealistic' ideas (winged horses, fiery dragons, and monstrous giants; *Treatise*, p. 12) entails pure imaginative efforts, so Fodor's confusion is innocuous, at least for his own and this section's purposes. Things will become different in the next section. From this point on, we will follow Fodor's convention of representing ideas/concepts with small caps. For an overall treatment of Hume's 'memory/imagination' distinction, see Wilbanks (1968: Ch. 2), Pears (1990: Ch. 3), Bennet (2001: 207–209), and Traiger (2011).

same time, makes a coherent whole of them. Besides, simple ideas, according to Hume's strong empiricist commitment, are exhaustively copies of impressions (*Treatise*, p. 8); but the same needs not be the case of complex ideas, for many of them are the product of 'imagination'—see fn.3, a faculty capable of joining ideas—themselves copies, without however copying their joints from impressions. Thus, from the projection of the dual (copy/imagination) mechanism onto the originally dual (simple/complex) taxonomy, it results a triple taxonomy of ideas: namely, (1) 'simple copies', (2) 'complex copies', and (3) 'complex images' —a set of labels for which only us must be blamed.[5]

One of the main points of Fodor's critique—and the one to be discussed here, is that Hume was wrong in believing that complex impressions contain joints directly reflecting sensed experiences—for experiences lack them to start with, which could be directly copied and translated into ideas. This was one of Hume's main empiricist sins, according to Fodor's reading. But also according to him, Hume's was nevertheless a rightly focused mentalist project that embraced two fundamental Cartesian stances, upon which successful modern RCTMs build: namely, (i) the concept of the mental as the site of a multilevel architecture of self-contained ideational systems (representationalism) and (ii) the idea of representations as the outset and outcome of mind-internal symbol manipulation processes (computationalism)—see Biro (2004). Hume's implementation of these theses—according to Fodor's exegesis—is captured in Figure 2.

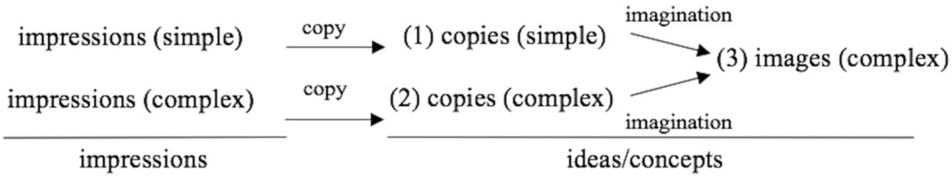

Figure 2: Hume's representational/computational theory of mind (Fodor's version).

Let us concentrate on the particular case of complex ideas/concepts—copies and images; (2) and (3) in the figure, which for obvious reasons are crucial for evaluating Hume's commitment with (a version of) the RCTM and, complementarily, the extent to which his empiricism was as radical as customarily assumed. In brief, our conclusion is that Fodor's image of Hume's RCTM is not completely accurate, but in a somehow unexpected direction: Despite the fact that there clearly exists an obvious lack of balance between the Baconian and Cartesian components of Hume's recipe for a future science of human nature, there are reasons to conclude that the weight of the latter relatively to the former was even heavier than Fodor believed it to be. Here follows our reasoning.

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[5] Note particularly that we use 'images' as a shortcut for the outcomes of 'imagination', in Fodor's sense. While we agree that the denomination may be misleading, considering previous uses of the term 'imagistic' as broadly applying to all kinds of ideas/concepts (see, for example, Garrett 2011: 50), yet we believe that in the specific context of Figure 2 above and Figure 3 below, the specialized use suggested here—on a par with 'copy/copies', or 'edit/edits', is clear and acceptable. These kinds of 'faculty/ideas' doublings are certainly typical of Hume (Traiger 2011: 59).

As already observed, Hume singled out two separate mechanisms in charge of bringing about the generation of complex copies (2) and images (3). In the case of images, as Fodor correctly observed, he appealed to the generative resources of 'imagination', a faculty capable of putting together independently remembered simple and complex copies, and adding new kinds of joints uniting them. Fodor's preferred example is UNICORN, but Hume's main illustration is much more complex than that: the idea corresponding to the city of New Jerusalem—NEW JERUSALEM, a biblical image for the reconstruction of the soul, in the (imagined) physical instantiation of which "pavement is gold" and "walls are rubies" (*Treatise*, p. 8). That Hume's complex examples are as a matter of fact more complex than Fodor's is not a negligible detail, as we shall presently show. So let's keep this in mind. As for copies, according to Fodor's construal complex ideas spring in its turn from the non-generative mechanism of 'copy', which just replicates the corresponding impressions, creating relatively less forceful and less violent reflexes therefrom. We think that here Fodor erred in his exegesis, though, as an examination of Hume's main example clearly demonstrates.

Hume specifically concentrates on the idea corresponding to the city of Paris—PARIS; or more accurately, the idea that Hume himself constructed after visiting Paris during his pre-*Treatise* stay in France. The importance of the fragment has been previously emphasized—for example, by Stroud (1977: 20) and Traiger (2011: 59), but without deriving all the far-reaching consequences that in our opinion it might inspire. PARIS, according to Hume, is not simply a faint version of the impressions left by the Paris he visited: It is, granted, a faint version of many such impressions… *less* many other such impressions that he also received from 1734 to 1737. In Hume's own account:

> I have seen Paris, but shall I affirm I can form such an idea of the city, as will perfectly represent all its streets and houses in her real and just proportions? (*Treatise*, p. 8)[6]

So, complex copies derive from processes that involve, surely among others, such operations as 'subtracting' and 'resizing' impressions, a much more creative (generative) computational procedure than merely a 'copy' mechanism. It is worth remembering that in the *Enquiry*, Hume enumerated a series of faculties that underlie the seemingly unbounded liberty of thought, which include 'compounding, transposing, augmenting, or diminishing the materials afforded us by the senses and experience' (*Enquiry*: p. 14).[7] While the immediate context of the quote suggests that Hume is narrowly referring to the labors of our capacity

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[6] It seems clear that Pears misreads this passage when he writes the following:

> You look down on Paris from a plane and get a complex impression of it: according to Hume, your singular idea of Paris is just a mechanical copy of this impression, and no selection or abstraction is needed before you can acquire it. (Pears 1990: 27)

Hume's intended sense is nicely captured in the following passage from Stroud:

> I have had a breathtaking impression of Paris from the steps of Sacré Coeur, but I cannot now form an idea which exactly resembles that impression. So there are […] impressions without exactly resembling ideas. (Stroud 1977: 20)

[7] We quote from the following edition: *An Enquiry Concerning Human Understanding*, ed. Tom L. Beauchamp. Oxford: Clarendon Press, 2000.

for fiction, a broader interpretation strikes us as legitimate when turning to his reflection in the *Treatise*, according to which such faculties are also recruited in the editing of complex realistic ideas with the distinctive seal of beliefs. Surely enough, the less complex an idea, the less operative the whole complex procedure; but by concentrating on these less complex, yet still intricate kinds of copies —like say, HORSE, COW, and so on, one misses the opportunity of capturing it in its full-fledged generative grandeur. Which certainly was Fodor's mistake, whose attention seems to be too much focused on such 'less complex' complex copies, corresponding to cows, unicorns, and similarly middle-sized, well-delimited entities. We thus disagree with Fodor's persuasion that Hume is fettered to the thesis that "the mind doesn't *add* anything to impressions in the course of getting from sensation to perception" (41, emphasis in the original); it actually, it adds *a lot* in the way to complex percepts.[8]

The moral is clear: Simple ideas are, within Hume's framework, systematiccally the result of a non-generative 'copy' procedure—which generates less forceful and violent versions of impressions—(1) in Figure 2; complex images are in turn the result of the generative powers of 'imagination'—which generates ideas with no external correlates via separate impressions—(3) in Figure 2; but an intermediate different category appears also to deserve recognition, corresponding to what according to Fodor are just complex copies—(2) in Figure 2, for complex ideas with external correlates via impressions are not just the product of 'copy'. Certain kinds of editing work, like 'subtraction' or 'resizing', are required by this class of ideas, a reason for which we suggest to name the procedure 'edit'—somehow reminiscent of Dennett's (1991) 'multiple drafts' model of consciousness—and which claim to be qualitatively different from just copying or imagining. If our conclusion is on the right track, Figure 2 above thus deserves to be amended along the following lines:

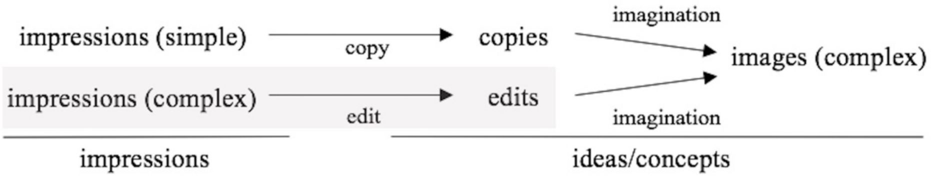

Figure 3: Hume's representational/computational theory of mind (revised version).

According to this interpretation, Hume's assertion above that "the rule is not universally true, that they [complex impressions/ideas] are exact copies of each other" (*Treatise*, p. 8) does not specifically apply to ideas/concepts resulting from the labors of imagination—that is, complex images, contrarily to what Fodor's interpretation entails. It also applies, and critically enough, to ideas/concepts resulting from the kinds of distortions representative of editing,

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[8] Stroud (1977: 20), Pears (1990: 19), Owen (2009), and Morris & Brown (2014) have emphasized that the copy principle (*sensu stricto*) only applies to the relation between simple impressions and ideas, but curiously enough they do not deepen into the question of which principle/mechanism had Hume in mind as regards the relation between complex variants of both kinds of percepts.

not just to the kinds of recombination appropriate to imagination.[9]

Against this interpretation, the objection may be raised that it does not seem to be compatible with Hume's basic principle, according to which the relation between impressions and ideas is 'character preserving'—our own designation: That is, "whatever is true of the one [an impression] must be acknowledg'd concerning the other [the corresponding idea]" (*Treatise*, p. 18). At first glance, editing certainly appears to be so strong an operation as to be incompatible with such character preserving principle. But maybe not at a second glance. Note that character preservation is saved across a wide range of "strength and vivacity", for the impression/idea relation is not subservient to "any particular degree" thereof (*Treatise*, p. 18). The claim naturally applies to the fading out of simple impressions into simple ideas. But it seems clear that something needs to be added when one tries to extend it to complex impressions/ideas, for in that case attention must also be paid to the different kinds of relations that may bring together different perceptions to compound more complex ones.

Let's turn to PARIS and, for the sake of the argument, let's also simplify the case by supposing that such a complex idea comprises an increasing number of simple ideas united by the relation of 'contiguity'. As shown, it is Hume's contention that in the transition from the corresponding impressions, many perceptions are lost, and the ones that remain become differently ranked relatively to each other in terms of strength, vivacity, and maybe other qualities like size, contour, and so on. It sounds reasonable to conclude that in as much as it does not destroy the underlying principle (contiguity, in this case), the resulting ideas/concepts—in the same individual at different times, or in different individuals at the same or different times—still count as instantiations of the same idea, despite losses and reconfigurations; so 'character preserving' is preserved. A nice way of conceptualizing these kinds of 'resizing' operations has been suggested to us by an anonymous reviewer, based on Gallistel's (1989, 1990) theory of representation for non-human cognition, inspired on the measurement theory of Stevens (1946) and later work; see Gallistel (1989, 1990) for references. According to this theory, mental representations and external contingencies stand on an isomorphic relation, but one based on specific still to-be-measured psychological variables. Thus, representations may exhibit variable-constrainedly re-dimensioned outputs ('resizing'), yet respectful of a fully isomorphic ('character preserving') underlying grid.[10] What seems to be clear is that complex operations leading

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[9] We are respecting Fodor's use of 'concept' as freely interchangeable with 'idea', for it is harmless regarding the subject matter of his and our enterprises. See, however, Pears (1990: 16–17), where the clarification is made that the latter must refer to bare mental 'data', while the former must do to the same data, but *qua* bearers of meaning.

[10] One must take into account, however, that these kinds of theories of representation are inherently non-symbolic, as it is the case with others, also more or less explicitly based on the idea of isomorphism like Churchland's (1989) n-dimensional vector spaces or Cummins's (1996) isomorphic structures. These systems represent in virtue of their own internal structure and not necessarily, as argued by Cummins (1996), because of there being any causal relation between representation and represented. Therefore, at this point Fodor and Hume would also have parted company, since, as pointed out by another reviewer, Hume would perhaps have felt quite comfortable with the idea, while Fodor, being and

from environmental impressions to ideas operate differently, i.e. not by just copying—subject only to the loss of 'strength and vivacity', or imagining—the distinctive character of which is its indirect relation with environmental impressions and its intensive use of recombination.[11]

The conclusion that one can reach from the observations above regarding Fodor's interpretation of Hume is twofold. Firstly, Fodor failed to appreciate the computational richness of ideas/concepts directly derived from complex impressions: Granted, they carry the seal of environmentally induced impressions; yet they also purport the application of rich generative—as opposed to just imitative—procedures. But secondly, Fodor's error serves to stress that his main tenet is nevertheless on the right track: Hume's computationalism is a sophisticated stance, an attentive reading of which reveals that it sometimes even defeats his empiricist commitments, as it is clearly the case in the realm of complex 'realistic' ideas—that is, complex copies or, better, edits. The next section is devoted to explore the consequences of this unexpected conclusion.

3. From Simple Impressions to Complex Concepts: What Hume Got Wrong (or Did He?)

Fodor put too much emphasis on how Hume dealt with representations not directly derived from experience (UNICORN, NEW JERUSALEM, and so on). He had good reasons for doing so, since according to his reading non-experienced representations must somehow be 'experienceable' in order not to destroy Hume's whole empiricist edifice. Hume guarantees this requirement, so Fodor's story goes, by granting that the ultimate constituents of complex representations fulfill the condition of being rooted in experience, plus positing what, from our contemporary perspective, might be characterized as a 'weak' compositional procedure—our own characterization, incapable of distorting such constituents in any relevant sense. Fodor is very clear in this respect, as witnessed by the following passage:

> Hume's psychological defense of empiricist epistemology consists of the claim that the content of *simple* concepts is empiricist (they just copy experiences), together with the assumption that compositional processes are semantically transparent (they add nothing to the content of simple concepts when they join them together into complex ones).
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> (95; emphasis in the original)

But according to Fodor, the second assumption is right away wrong, for when joined together, two simple concepts remain intact only in as much as they do not compose; if they compose, then new conceptual material inescapably arises. Thus the idea of LOVER, to offer an illustration of a reliably complex concept, when applied to the idea of an individual—say, JOHN, automatically

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externalist about content, wouldn't. The issue is quite relevant, but getting in full into it would take us too far afield.

[11] Obviously enough, imagining may also exhibit the distinguishing signatures of editing, but indirectly, in as much as the former may feed with the outcomes of the latter.

implies the idea of another individual—say, MARY—as BEING LOVED, which is obviously not an experience-based idea itself. On this account, Fodor concludes that Hume, in order not to betray his empiricist commitment, appoints the task of composing complex representations to a computational apparatus that betrays the manner how a human mind actually composes them. In other words, Hume's greatest weakness was to put too much confidence on the powers of a weak compositional procedure.

As we have been suggesting in the previous section, things turn out not to be for Hume as neatly delineated as Fodor contended. Important consequences follow. The heart of the matter has to do with how Fodor, consistently through his monograph, emphasized as essential the link between the mind's higher representational powers and 'pure imaginative efforts' (see fn. 3), of the kind required to compose ideas like NEW JERUSALEM. Wrongly, we claim, for it seems clear from Hume's own statements that equally powerful procedures are also entailed by complex representations more directly anchored on experience—for example, PARIS—that, as argued above, happen not to be just copies. Therefore, at odds with Fodor's reading, 'imagination' is not the faculty of composing unrealistic ideas, but the faculty of composing *tout court*.[12]

Fodor writes, as capturing the gist of Hume's 'faculty of imagination', that it is the mental quality that grants that "there's no end to the things one can think of", despite "the population of simple concepts is fixed" by experience. So there exists a division of labor of sorts between imagination and experience, in that the former endlessly opens the realm of the thinkable, while the latter puts "an end to the things one can think of" (85) within that realm. We agree that all this captures Hume's idea of the imagination; but only partially so and, in our opinion, not in its core, more essential aspect. According to our own view, Fodor's statement above ("there's no end to the things one can think of") needs to be supplemented with the following crucial one: *There is no end in the way one can think of a particular 'real' something*. According to our own interpretation, it is this statement that more directly captures what Hume's 'imagination' does, while Fodor's counterpart surely captures a sort of side-effect of its natural powers. This is, assumedly, a contentious claim, and one that deserves to be neatly justified. The key of our argument is again PARIS, so let's visit one more the City of Light.

Remember that it is Hume's contention that one cannot construct an idea of Paris roughly based on the impressions received after visiting the city. No

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[12] Certainly enough, Fodor writes that "for Hume, imagination is the faculty of compositionality" (94), but his continuously restricting the faculty's natural range of applications to pure imagination misrepresents Hume's explicit claims. Nonetheless, in the same page, Fodor misquotes Hume, we believe, when the former refers to the latter's claim about the "*liberty of imagination to transpose and change its ideas*" (*Treatise*, p. 12; emphasis in original), as pinpointing pure imaginative compounds. Hume certainly claims (ibid.) that "[t]he fables we meet with in poems and romances put this entirely out of the question", but this cannot be read as contending that fables are the only realm on which imagination applies. Imagination is as present in the enacting of recollected past events as it is in fabulating them (*Treatise*, p. 11). One may feel tempted to conclude that it is Hume's position that because recollecting entails imagining, fabulating becomes accessible to the mind—but not the other way around.

mind—not even an extremely hypermnesic one—could do that. Minds are doomed to be manipulative in order to be viable at all as the fabric of ideas. This is how the faculty of imagination actually enters into the economy of mind according to Hume's narrative: Impressions that massively impact the representational mind need to pale into shadowy ideas in order to serve as the bricks for representing complex experiences—that is, 'memory' must give way to 'imagination' (*Treatise*, § 1.1.3; see fn. 4). In the way, impressions are lost, resized, transposed, and recomposed (*Treatise*, p. 8; *Enquiry*, p. 14)—or, as summarized in the previous section, 'edited' for representation. As nicely captured by Wilbanks (1968: 72ff.), forming ideas, and not just uniting and separating them, is one of the powers of imagination, which is assisted by a principle of liberty. Consequently, a particular 'real' something—Paris—may be variously (as a matter of fact, endlessly) represented at different times within the same mind, not to speak of different minds at the same or different times. What Fodor missed about Hume's 'imagination' is its complementary role to the one of 'memory' in the economy of mind, as well as the richness of its effects on representations, for contrarily to Fodor's partial reading, they amount to much more than simply 'gluing' ideas. Such effects, while primarily apt to countervailing the inconveniences of rough memory, also pave the way to the boundless scope of things one can think of.

What we conclude is that Hume's computational apparatus is not as 'weak' as Fodor believed it to be. On the contrary, it is rather 'strong': It deletes, augments, diminishes, transposes, and composes, at a minimum. If something is clear, it is that much against Fodor's construal, it 'adds' a lot—or potentially so—to the content of previously processed representations, either by memory or by prior imaginative efforts applied to impressions directly rooted in experience. Fodor failed to appreciate all this, which defies the crucial point of his whole argument: Hume doesn't appear to be as strongly committed to the empiricist stance as to believe that computations cannot cause representations to depart in essential respects from the experiential patterns that impress the mind. Fodor contends that Hume had a problem with this, but we think that he hasn't.

So, what's the bottom line? Paradoxically enough, grist to Fodor's mill: Hume's empiricism and computationalism are more balanced than Fodor appreciated. Hume was a more committed representation/computational theorist than even Fodor's representational/computational eyes were capable to detect. But in the end, did Hume get something wrong? Surely he did, and Fodor got it right: Hume's computational mind seems to lack, at least, the power of 'embedding' ideas within ideas: It is not enough to put DOG and CAT together to get PET; what one really needs is to embed them within an overarching representation. Similarly, it is not enough to put HORSE and HORN together to get UNICORN, or to put twenty *arrondissements municipaux* to get PARIS; and so on and so forth. But considering the considerable richness of Hume's combinatorial processes, and that they were clearly advanced as a tentative list, it is not too risky to conclude that he would have been willing to accept 'embedding' in the list without sensing this was betraying the ultimate anchoring of representations in experience. We thus disagree with Fodor's thesis that Hume was vigilantly avoiding enriching associations for he fully understood "what it [was] going to cost him", namely, "his empiricism" (Fodor 2003: 119). As a matter of fact, Hume's associations are rich from the start, clearly much more than what Fodor referred to as the "bare bones Law of Association", which he (Fodor) felt so reasonably committed to fight against. But it was probably not so needed, we believe, to get Hume off this hook.

According to our interpretation, Hume's science of human nature was even closer to contemporary RCTM than Fodor explicitly guessed; and Fodor's own version of RCTM was closer to Hume's science of human nature than the latter could have been possibly prompt to admit. Obviously enough, this must not be read as positing that no serious gaps exist between them, since, as commented by an anonymous reviewer, key contributions of mind to meaningful representations were certainly far away from Hume's Cartesian horizon—e.g. logical form composition on a Turing-style basis, or the kinds of additive meanings that obtain 'beyond' strict composition.

4. Conclusion

Hume was, according to Fodor's apt description, a 'Cartesian naturalist' (Ch. 1): As a Cartesian, he treated 'ideas' as what make things they are about 'thinkable'; as a naturalist, he tried to avoid any metaphysic apriorism about what ideas are, by rigidly anchoring them in experience. This was not an easy tension, as anyone can appreciate considering how the former stance approximated him to contemporary RCTM, while the latter inclined him toward present-day Pragmatism. According to Fodor's diagnosis, Hume succeeded in avoiding the pragmatists' original sin of plainly ignoring the structure of mind, yet he had to pay the price of exacerbating his empiricism, at the cost of sacrificing the whole success of his computational project. In this note we have partially disagreed with this diagnosis. Sure enough, Hume's RCTM was not a fully successful one, but as Fodor himself implicitly acknowledged (115), such was an aspiration completely out of place before the advent of Turing's contributions.

In this note we have claimed that Hume's purported failure was of a different, more justifiable kind: He just didn't manage to carry to completion the project of identifying the powers by which a humanly structured mind transforms simple experienced impressions into complex representations. But in all likelihood, he didn't manage for he didn't even intend to fulfill it. It was not among his main preoccupations, which justifies his loose way of referring to specific computational operations, both in the *Treatise* and in the *Enquiry*. Hume's main preoccupation seems to have been one that was already in his mind well before he actually started building his science of human nature: namely, correcting the 'natural philosophy' of the forerunners of such a project "of being entirely hypothetical, & depending more upon invention than experience".[13] We have argued that in doing so, Hume left enough elbow room to a more sophisticated cognitive architecture than commonly thought, which, in the end, makes Fodor's claim that the "*Treatise* is the foundational document of cognitive science" (134) even truer.

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[13] From a letter dated in 1731. The quote is from the following edition: *The Letters of David Hume*, vol. 1, ed. J.Y.T. Greig, Oxford: Clarendon Press, 1932, p. 10.

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Wittgenstein and Biolinguistics: Building upon the Second Picture Theory

John Bolender

Circa 1930, Wittgenstein began to develop a theory of semantics in terms of distinct representational systems (calculi) each constructed from measurement scales. Impressed by the heterogeneity of measurement scaling, he eventually abandoned the effort. However, such a project can be continued in the light of later developments in measurement theory. Any remaining heterogeneity can be accounted for, plausibly enough, in terms of the facultative nature of the mind/brain. Developing such a theory is potentially a contribution to biolinguistics. The symmetries and asymmetries of the measurement scales suggest self-organization in brain activity, further suggesting a connection between such a neo-Wittgensteinian approach to the thought systems and minimalist approaches to syntax.

Keywords: calculus model; conceptual-intentional systems; measurement theory; *Satzsysteme*; picture theory; self-organization

1. Introduction

Practitioners of biolinguistics, the attempt to understand language by situating it within a biological framework, are often drawn to appeals to symmetry and beauty (Chomsky 2005). Lyle Jenkins (2000: 147) suggests that an important strategy in biolinguistics should be to seek confirmation of Einstein's observation that "symmetry dictates design". Juan Uriagereka (1998) notes that the branching form of a structural description exhibits dilation symmetry, by virtue of being fractal. The point is to discover how much of syntax 'comes for free', in the sense of being directly the result of physics, as opposed to the molding and shaping of differential reproduction as genetically encoded.

> In the study of the inorganic world, for mysterious reasons, it has been a valuable heuristic to assume that things are very elegant and beautiful. If physicists run across a number like 7, they may assume that they have missed something, because 7 is too ridiculous a number: it must really be 2^3, or something like that. […] Similar intuitions have been reasonably successful in the study of language. If they are on target, it may mean that language is rather special and unique, or that we do not understand enough about other organic systems to see that they are much the same, in their basic structure and organization. (Chomsky 1996: 30)

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Despite occasional inclusive remarks, such as the above reference to "other organic systems", this approach has usually focused on the computational core of the language faculty and its interfaces. In the biolinguistics literature, it is more common to find observations regarding beauty limited to syntax, such as the following: "[T]he principles of language are determined by efficient computation and language keeps to the simplest recursive operation designed to satisfy interface conditions in accord with independent principles of efficient computation. In this sense, language is something like a snowflake, assuming its particular form by virtue of laws of nature" (Berwick & Chomsky 2016: 71). Less attention has been paid to the conceptual-intentional systems, the systems of thought.

One aim of this article is to show that the picture theory of Ludwig Wittgenstein (ca. 1930) holds promise as a potentially biolinguistic approach to the thought systems, by reason of revealing symmetry and beauty in those systems. When the picture theory of 1930 is developed as a generative system—contrary to Wittgenstein's own wishes, it must be said—then the relevance of third-factor considerations (Chomsky 2005) to the thought systems becomes apparent. The systems of thought also turn out to be like a snowflake, in other words.

2. The Second (Version of the) Picture Theory

Wittgenstein's picture theory of meaning has a long and interesting history, even if not an entirely happy one. An atomistic version of the theory forms the centerpiece of his first book, *Tractatus Logico-Philosophicus* (Wittgenstein 1922), later replaced by a holistic version in his second book *Philosophical Remarks*, completed in 1930 (Wittgenstein 1975a). While the notion of a measurement scale was important for the theory from the very beginning,[1] the concept of measurement scaling assumes a much greater and more explicit role in the later holistic version. It is the role of scaling which, as I shall argue, reveals how beauty and symmetry enter into processes in the thought systems.

Unfortunately, Wittgenstein was developing this approach to semantics primarily in the years 1929 and 1930, prior to important developments in measurement theory. As a result, the theory was never fully developed. In fact, his frustration in regard to the hope of fully developing the theory eventually led to his adopting an anti-theoretical stance, most famously elaborated upon in *Philosophical Investigations* (Wittgenstein 2001). However, when one considers advances in measurement theory, one becomes optimistic of further developing the holistic version of the picture theory. In fact, it is reasonable to expect the

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[1] In his earliest reference to the picture theory, Wittgenstein mentions measurement and picturing as though they are essentially the same relation between proposition and fact. On 24 November 1914, he wrote in his notebooks that "[p]roposition and situation are related to one another like the yardstick and the length to be measured. […] In the proposition we hold a proto-picture up against reality" (Wittgenstein 1979: 32). Also note "[t]he proposition is a measure of the world" (Wittgenstein 1979: 41), written in the following March (cf. Wittgenstein 1922: §2.1512). For a later perspective on this early appeal to scaling, see (McGuinness 1979: 185, Stern et al. 2016: 2332–2376).

development of a kind of generative grammar for the representational systems which Wittgenstein posited in his second book, i.e. a grammar for specifying calculi, just as the particular grammar of a natural language specifies structural descriptions. This would not, however, be a replacement for the Merge-based generative grammar familiar in minimalist linguistics, since it would pertain to systems outside the narrow language faculty. It would be complementary.

The version of the picture theory at issue here is the holistic version circa 1930, formulated nearly a decade after *Tractatus*. One could even, properly enough, speak of the holistic version as a *second* picture theory. The term 'picture theory', in fact, is so closely associated with *Tractatus*, it may be wise to avoid the phrase 'picture theory' in reference to the later holistic view. From now on, I will speak of 'Wittgenstein's Second Theory' or, simply, 'The Second Theory', thus minimizing use of the word 'picture'. The Second Theory is a partially developed viewpoint, found primarily in Wittgenstein's "Some Remarks on Logical Form" (Wittgenstein 1929), *Philosophical Remarks* (Wittgenstein 1975a), and conversations recorded by Friedrich Waismann (McGuinness 1979). (I will, even so, sometimes cite pre-1929 work as belonging to The Second Theory when it seems appropriate to do so, on the plausible assumption that many ideas from the first picture theory were meant to carry over into The Second Theory.)

The core idea in The Second Theory is that semantics is measurement: The mind/brain uses measurement scales to make pictures of 'spaces', where a space is a range of logical possibilities for some domain of phenomena (Wittgenstein 1975a: Ch. IV & p. 317). The semantic properties of a scale are partially a matter of the internal structure of the scale, its 'multiplicity', and also partly a matter of how the scale is used (Wittgenstein 1922: §3.326). The use crucially depends upon the multiplicity; without the right multiplicity, there could be no relevant use. Scales are sometimes combined into complex structures, 'calculi' (Wittgenstein 1975a, McGuiness 1979), each scale of a given calculus being a picture of a dimension of the corresponding space. A given calculus is thus a picture of the pertinent space. (It is the *construction* of these calculi which raises the possibility of a generative grammar of sorts, a point to be expanded upon later.)

As an example of holistic picturing, consider the waggle dance of the honeybee. A bee observing another bee perform the dance forms a picture in its brain homomorphic to the dance. This picture presupposes a multi-dimensional space, each dimension of which corresponds to a scale of measurement. The space, as represented in the brain, is a picture of the corresponding space in the external world, the latter being a range of possible locations of food or water. The specific dance is a picture of a possible fact, just as the space of possible dances (i.e., the calculus) is a picture of the space of all possible facts about location. The meaning of the mental representation crucially depends upon the internal structure of the calculus, but also depends upon the use made by the bees, the latter crucially depending upon the former. Semantics is holistic in that the specific dance has no meaning unless the calculus has meaning, i.e. the former is only a picture of a fact by reason of the latter being a picture of the pertinent space of possible facts.

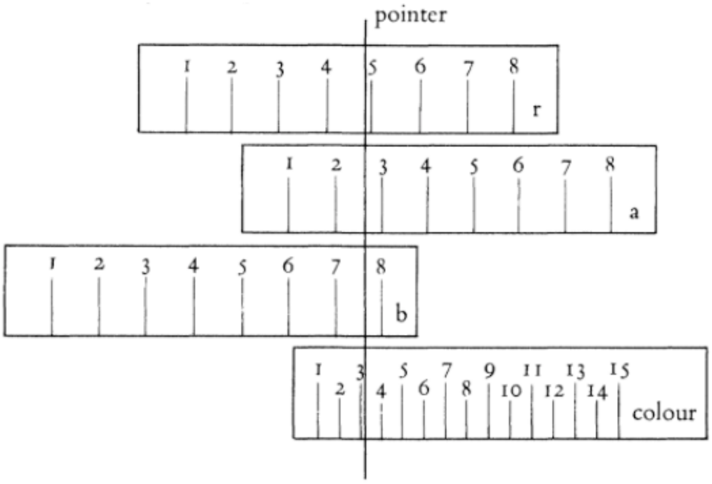

Figure 1: Representation of a calculus, or Satzsystem *(propositional system). This calculus pictures the ranges of possible positions, colors, and radii of a circle in a two-dimensional space. The example is from Wittgenstein (1975a: §84).*

Writing to G. E. Moore in 1930, Russell noted, in reflecting on recent conversations with Wittgenstein regarding his manuscript *Philosophical Remarks*, that Wittgenstein "uses the words 'space' and 'grammar' in peculiar senses, which are more or less connected to each other. He holds that if it is significant to say 'This is red,' it cannot be significant to say 'This is loud.' There is one 'space' of colours and another 'space' of sounds. […] Mistakes of grammar result from confusing 'spaces'" (Russell 1951: 297). The grammar of a given calculus consists of the measurement scales making up its dimensions. "The syntax of ordinary language […] does not in all cases prevent the construction of nonsensical pseudo-propositions (constructions such as 'red is higher than green' […])" (Wittgenstein 1929: 162). "Red is higher than green" violates grammar because the scales which constitute the color calculus are distinct from the scales constituting the pitch calculus. The sentence "This is red and loud", when it expresses a proposition, must thus be analyzable, on the level of the thought systems, into something along the lines of "A is red, and B is loud". Each calculus, loosely speaking, represents its own world; the logical connectives (such as 'and', 'or', etc.) link these worlds.

Note, however, that this is only a *theory* of mental representation if measurement scaling is a specific type of thing. Wittgenstein was sensitive to the various sorts of measurement scaling, a point to be expanded upon later. Struck by this variety, he eventually came around to the view that logic and language have no essence. There is too much variety for theory to be possible, or so he came to believe. Note Wittgenstein's eventual anti-essentialism with regard to both number and language in *Philosophical Investigations* (Wittgenstein 2001: §§65–71). Given his earlier meditations on the varieties of scaling (Wittgenstein 1975a, McGuinness 1979) and the fact that the various scales can be used to define different types of number (Ellis 1966: Ch. IV, Wiese 2003: Ch. 1), an anti-essentialism with regard to scaling was almost certainly on his mind in writing about number in *Investigations*.

However, as would be revealed by advances in measurement theory beginning in the late 1940s, there is some degree of beauty and formal simplicity underlying the types of measurement scales. It is at this point that the prospect of self-organization in neural activity arises with regard to the Second Theory. I suggest that, encouraged by these developments, one should pick up the thread and continue theorizing precisely where Wittgenstein left off. If the Wittgensteinian calculi provide insight into the representational powers of non-linguistic faculties, then the beauties of measurement theory could reveal that language is not so unique in this regard, since other systems also exhibit beauty.

There is another source of heterogeneity among logical forms, namely the contrast between forms arising within a calculus versus the recursive/combinatorial operation linking representations to yield molecular forms. In other words, there is the distinction between the language faculty and the thought systems, especially in terms of how the latter function apart from the influence of language. Advances in measurement theory will not make this kind of heterogeneity go away. However, biolinguists should be comfortable with it, as it merely reflects the facultative nature of mind (Hauser et al. 2002).

3. The Atomic and the Molecular

The Second Theory, like the earlier version of the picture theory in *Tractatus*, assumes a potential analysis of representations into atomic representations. Each calculus determines logical relations among the atomic representations belonging to it.

> If we try to analyze any given propositions we shall find in general that they are logical sums, products or other truthfunctions of simpler propositions. But our analysis, if carried far enough, must come to the point where it reaches propositional forms which are not themselves composed of simpler propositional forms. We must eventually reach the ultimate connection of the terms, the immediate connection which cannot be broken without destroying the propositional form as such. The propositions which represent this ultimate connexion of terms I call, after B. Russell, atomic propositions. They, then, are the kernels of every proposition, *they* contain the material, and all the rest is only a development of this material.
>
> (Wittgenstein 1929: 162–163)

To say that P is an atomic proposition—what Wittgenstein usually referred to as an elementary proposition—is to say that, if P were written as a compound proposition, its compound form would not be essential to its truth-value. For example, if P is "a is red" one could rewrite it as "a is red, and if b is blue then b is blue". This would be extensionally equivalent to the original proposition. Given that "if b is blue then b is blue" is logically true, it can be deleted from the proposition without altering the truth conditions (see Wittgenstein & Waismann 2003: 245). This stands in contrast to "a is red, and b is blue" where a and b are distinct space-time regions. This latter would be a molecular proposition, since one cannot remove either conjunct without arriving at a proposition with different truth conditions than the original. The elementary propositions can be combined, according to a recursive operation, to form molecular propositions (Wittgenstein 1922: §§6–6.01). For example, if P, Q, and R are elementary propositions, then P & (Q & R) is a molecular proposition. Connectives introduce new logical relations, including those between calculi.

In *Tractatus*, Wittgenstein affirmed that there are no logical relations between elementary propositions other than consistency and self-implication, which are merely degenerate or limiting cases. True logical relations arise at the molecular level, and are captured in truth tables, according to this early view. However, by 1929, Wittgenstein came to realize that there are logical relations of exclusion among the readings of a single measurement scale even without molecular structure. In any specific case of measurement, a given reading logically excludes every other reading for that scale: "But from 'a is now red', 'a is now not green' follows, and so elementary propositions in this sense aren't independent of each other like the elementary propositions in the calculus I described earlier—a calculus to which I assumed the entire use of propositions must be reducible—seduced by a false concept of such a reduction" (Wittgenstein 2013: 82). This is a general property of measurement: "[A] point mass can only have *one* velocity at a time, there can only be *one* charge at a point of an electrical field, at *one* point of a warm surface only one temperature at one time, at one point in the boiler only *one* pressure etc." (Wittgenstein 1975a: §81).

Furthermore, there are arithmetical relations among the readings of a scale, e.g. the transitivity of an ordinal scale, which cannot be captured by truth tables. In fact, it is by reason of these arithmetical relations that the word 'calculus' is appropriate. Wittgenstein thus concluded that "[o]ne could surely replace the logic of tautologies by a logic of equations" (quoted in Hintikka 1996: 85). This is an overstatement, since one would also have to include relations of greater-than and less-than, e.g. in ordinal scaling. It is also an overstatement by reason of the fact that one would still need a logic of tautologies at the molecular level. Even so, the quote is useful in illustrating Wittgenstein's perception that arithmetical relations are even more basic than truth-functional relations. Truth-functional relations presuppose these calculi, thus turning on its head the older view (Russell 1919) that arithmetic was reducible to logic, or some combination of logic and set theory.

4. Prelinguistic Systems

The picture theory of Wittgenstein, both in *Tractatus* and circa 1930, was intended as an account of mental representation. This is explicit in *Tractatus*: "The logical picture of the facts is the thought" (Wittgenstein 1922: §3), and "[t]he thought is the significant proposition" (Wittgenstein 1922: §4).[2] Note also the remark Witt-

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[2] This is why Steven Pinker was unfair to Wittgenstein in speaking scornfully of his remark "*The limits of my language* mean the limits of my world" (Wittgenstein 1922: §5.6; cf. Pinker 2007: 134). At any rate, Pinker was unfair in trying to link the remark to the Sapir–Whorf hypothesis. Wittgenstein was not speaking of the limits of German or any other natural language, at least not specifically. He was, rather, speaking of the sum total of all possible mental representation. Perhaps one could still question the statement, or puzzle over what

genstein made in a lecture of 1930, as recorded in G. E. Moore's notes: "What sort of harmony must there be between thoughts & the world? Only that the thought must have logical form; & without this it wouldn't be a thought" (quoted in Stern et al. 2016: 2520). The point is that the calculus must have the same multiplicity as the relevant space of facts, the calculus here being something mental.

Given that the picture theory, including Wittgenstein's Second Theory, is a theory of mental representation, it is in no way alarming to realize that some of Wittgenstein's calculi are not language-like. This simply reflects the fact that not all thought is language-like. Some Wittgensteinian calculi are not language-like by virtue of not exhibiting discrete infinity (Bolender 2017). Within the biolinguistic paradigm, discrete infinity is understood to be biologically rare and, within the domain of cognition, uniquely human and wholly due to language (Hauser et al. 2002, Berwick & Chomsky 2016). Specifically, it is taken to be the result of recursion, usually understood as Merge (Chomsky 1995). Hence, biolinguists seldom recognize any reason to posit a Merge operation in the systems of thought.[3,4]

Consider the calculus illustrated in Figure 1 above. It exhibits a kind of infinity but not the infinity resulting from the recursive combination of discrete constituents. It exhibits infinity of the same sort as the waggle dance of the honeybee: "Between any two signals there is in principle another, signaling a distance in between the first two, and this continues down to the ability to discriminate" (Chomsky 1988: 169). One finds here, in other words, either discrete finitude (finite due to performance limitations) or continuum infinity.

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exactly it was supposed to mean, but it is not as patently absurd as saying that the limits of German were the limits of Wittgenstein's world.

[3] A reviewer for this journal suggests that the claim made here conflicts with the following passage from Chomsky: "[T]he Basic Property is generation of an unbounded array of hierarchically structured expressions mapping to the conceptual-intentional interface, providing a kind of 'language of thought'—and quite possibly the only such LOT, though interesting questions arise here" (Chomsky 2016: 13). The referee suggests that this passage indicates that Chomsky believes that the thought systems also utilize Merge.

My interpretation of the passage differs, however. In fact, the whole point in Chomsky's speaking of interfaces is to imply that the systems of thought do not produce indefinitely many hierarchically structured expressions independently of language. Chomsky speaks of the language faculty as LOT, because he recognizes it as playing a role in cognition by means of the CI interface. (For a brief discussion of one of the "interesting questions" which Chomsky alludes to, see fn. 4 right below.) That Chomsky does not equate language with thought itself should also be clear from the following quote from the same book: "[F]undamental properties of language design indicate that a rich tradition is correct in regarding language as essentially an instrument of thought, *even if we do not go as far as Humboldt in identifying the two*" (Chomsky 2016: 16, emphasis added).

[4] One apparent anomaly for this approach is the fact that people who lose syntactic ability in adulthood sometimes continue to show evidence of recursion in cognition, for example in mathematics. But this does not show that recursion is an intrinsic feature of the thought systems, since "language grammar might provide a 'bootstrapping' template to facilitate the use of other hierarchical and generative systems, such as mathematics. However, once these resources are in place, mathematics can be sustained without the grammatical and lexical resources of the language faculty" (Varley et al. 2005: 3523). Even if the thought systems do somehow form something analogous to the Merge operation, they may only be able to do so using language as a kind of ladder which is subsequently discarded at some point in ontogenesis. Its being discarded would be evident in cases of agrammatism when accompanied by numerical literacy.

That at least some calculi exhibit continuum infinity is clear from Wittgenstein's first published attempt to articulate The Second Theory, or a fragment thereof.

> If, now, we try to get at an actual analysis, we find logical forms which have very little similarity with the norms of ordinary language. We meet with the forms of space and time with the whole manifold of spacial and temporal objects, as colours, sounds, etc., etc., with their gradations, continuous transitions, and combinations in various proportions, all of which we cannot seize by our ordinary means of expression. And here I wish to make my first definite remark on the logical analysis of actual phenomena: it is this, that for their representation numbers (rational and irrational) must enter into the structure of the atomic propositions themselves. I will illustrate this by an example. Imagine a system of rectangular axes, as it were, cross wires, drawn in our field of vision and an arbitrary scale fixed. It is clear that we then can describe the shape and position of every patch of color in our visual field by means of statements of numbers which have their significance relative to the system of co-ordinates and the unit chosen. Again, it is clear that this description will have the right logical multiplicity, and that the description which has a smaller multiplicity will not do.
>
> (Wittgenstein 1929: 165)

The calculus, in this case, must have representational powers corresponding to the real numbers in order to be homomorphic with the space of possible visual sensations. It is in this sense that the atomic propositions have real numbers coded into their structure. Relations of logical implication among numbers turn out to be primary, since they can be found at the level of the atomic proposition.

The reference to numbers here does not mean that the calculus in question is a system of discrete infinity. For a Wittgensteinian calculus is not, in every case, a system for combining discrete objects. The notion of calculation or equation, at least as it appears in early intermediate Wittgenstein, should not be taken to involve discrete objects or, at least, not in every case. In some cases, a number is not a digit but a point in a continuous space. Consider Wittgenstein's attempt to illustrate a calculus for representing the space of possible colors (Figure 2); the system represented is not a particulate system but a blending system.[5] The calculus in Figure 2 only contains numbers insofar as each point in the continuous structure represents a number.[6]

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[5] Abler (2005) observes that complex systems divide into two types: particulate and blending. A particulate system consists of building blocks in hierarchical arrangement. Such a system is combinatorial and open-ended, language being a classic illustration. A particulate system stands in contrast to a blending system.

> Continuous variation along one or a few dimensions is the very definition of a blending system. In spite of the panoramic grandeur and local fascination, geology is a blending system. Hills, plains and valleys don't form combinations with one another to create something with properties beyond those of hills, plains, and valleys. Not the way atoms do." (Abler 2005: 70–71)

Wittgenstein's calculus for representing possible colors is a blending system, as it exemplifies continuous variation along dimensions.

[6] Wittgenstein would later reject the double-cone representation appearing in Figure 2 (Wittgenstein 1977). But he rejected it for not including enough dimensions (e.g. luminosity, transparency), leaving the current point at issue unaffected.

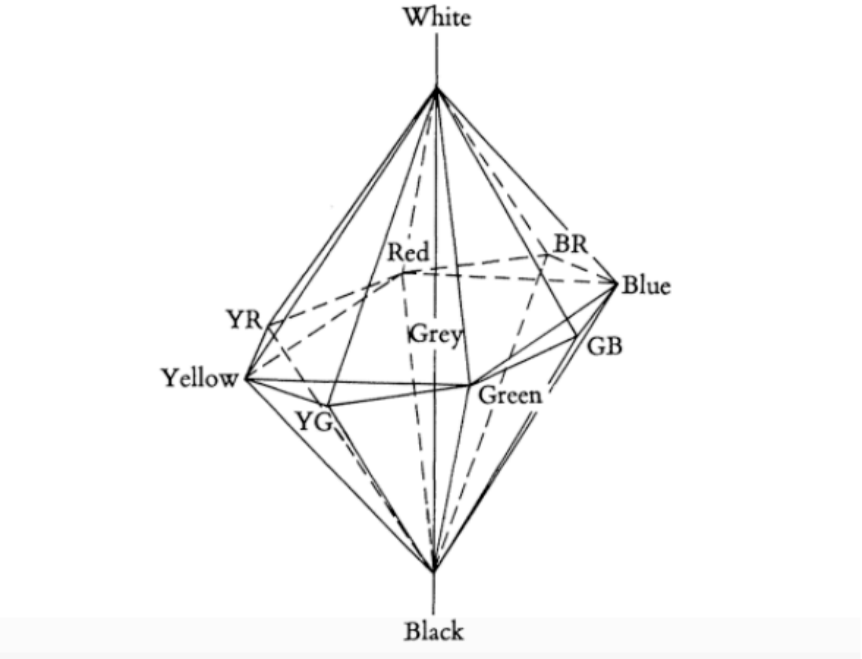

Figure 2: Wittgenstein's double-cone representation of color space. "If we represent the colours by means of a double-cone, instead of an octahedron, there is only one between on the colour circle, and red appears on it between blue-red and orange in the same sense as that in which blue-red lies between blue and red. And if in fact that is all there is to be said, then a representation by means of a double-cone is adequate, or at least one using a double eight-sided pyramid is" (Wittgenstein 1975a: §221).

Figure 2 illustrates a continuous calculus, not Merge-like in any way. It is true that the real numbers are definable in terms of operations on the naturals, and the naturals exhibit discrete infinity. However, in Figure 2, one finds a system of infinite multiplicity not presupposing discrete infinity. One has here the reals without the naturals.

I earlier noted that *some* Wittgensteinian calculi are not language-like by reason of exhibiting continuum infinity; note that there are others which are not language-like by reason of exhibiting discrete finitude. Once again, this is an encouraging feature of Wittgenstein's Second Theory since it underscores the potential here for understanding the form of representations outside the language faculty. Before considering examples from Wittgenstein, let's review the distinctions in question:

> To put it simply, each sentence has a fixed number of words: one, two, three, forty-seven, ninety-three, etc. And there is no limit in principle to how many words the sentence may contain. Other systems known in the animal world are quite different. Thus the system of ape calls is finite; there are a fixed number, say, forty. The so-called bee language, on the other hand, is infinite, but it is not discrete. A bee signals the distance of a flower from the hive by some sort of motion; the greater the distance, the more the motion. Between any two signals there is in principle another, signaling a distance in between the first two, and this continues down to the ability to discriminate.
>
> (Chomsky 1988: 169)

In addition to those Wittgensteinian calculi which are formally analogous to bee signals, there are also such systems which are formally analogous to ape calls. In a conversation with Friedrich Waismann early in 1930, Wittgenstein observed that "[w]hat I admittedly do not know is how large the domain of arguments is. And there might, for example, be only two. (Telephone dialling: free, in use—here we know that only these two values exist and they depict reality. An intermediate position does not signify anything. No transition.)" (quoted in McGuinness 1979: 90). In other words, a given dimension of such a system need not be continuous, but may consist of a finite set of logical possibilities. Wittgenstein also made the point in writing.

> What we have recognized is simply that we are dealing with yardsticks, and not in some fashion with isolated graduation marks. […] We might think of the signals on a ship: 'Stop', 'Full Speed Ahead', etc. Incidentally, they don't have to be yardsticks. For you can't call a dial with two signals a yardstick. […] If I say I did not dream last night, I must still know where I would have to look for a dream (i.e. the proposition 'I dream', applied to this situation can at most be false, it cannot be a nonsense). I express the present situation by a setting—the negative one—of the signal dial 'dreams—no dreams'.
> (Wittgenstein 1975a: §§84 & 86)

The examples which Wittgenstein gives here are recognizable as instances of what would later be called 'nominal scaling' (Stevens 1946). A nominal scale consists of labels, each label corresponding to a property. On a questionnaire, for example, one might encounter the question "Are you a smoker? Yes or no". Or one might encounter "State your political party". Each of these questions measures the thing, such as a person, simply by putting it into the proper slot in a list of categories. Hence, among the Wittgensteinian calculi, one finds both alternatives to discrete infinity, namely continuum infinity and discrete finitude.

In his *Tractatus*, Wittgenstein may have succeeded in avoiding the appearance of heterogeneity by naively assuming that all measurement is reducible to nominal scaling. Consider the following illustration of representation in *Tractatus*:

> An illustration to explain the concept of truth. A black spot on white paper; the form of the spot can be described by saying of each point of the plane whether it is white or black. To the fact that a point is black corresponds a positive fact; to the fact that a point is white (not black), a negative fact. If I indicate a point of the plane […], this corresponds to the assumption proposed for judgment, etc. etc. (Wittgenstein 1922: §4.063)

The only possible judgment for a point, in this case, would be whether it belongs to the scale (being black) or does not (being "white", apparently a catch-all for simply not being black)—a very simple form of nominal scaling. This sort of picture theory would be atomistic, but falls short of plausibility by overlooking phenomena which resist nominal scaling. Nevertheless, it still serves to illustrate how a calculus can be composed of nominal scales. This type of calculus is essentially identical to what Quine would later call a "matrix of alternatives":

> The notion of information is thus clear enough nowadays when properly relativized. It is central to the theory of communication. It makes sense relative to one or another preassigned matrix of alternatives—one or another checklist. You have to say in advance what features are going to count. Thus consider the familiar halftone method of photographic illustration. There is a screen, say six by six inches, containing a square array of regularly spaced positions, say a hundred to the inch in rows and columns. A halftone picture is completely determined by settling which of these 360,000 points are black. Relative to this screen as the matrix of alternatives, information consists in saying which places are black. Two paintings give the same information, relative to this matrix, when they determine the same points as black.
>
> (Quine 1986: 4)

This example illustrates how a calculus exhibiting discrete finitude, even when based upon the simplest kind of nominal scaling, can be informationally rich.

5. Scales as Constituting Essence

Wittgenstein's abandoned second philosophy of logic is a torso in the same sense that one speaks of an unfinished work of art as a torso. One can make progress in developing the torso by considering developments in measurement theory. The aim here is to arrive at a conception of logical form for *natural logic*, by which I mean the theory of how logical relations are represented in the mind/brain. Given that the logic in question is natural logic, a more developed form of Wittgenstein's second philosophy of logic has the potential to connect with work in cognitive science.

Measurement scales also play a fundamental role in Relational Models Theory (RMT) in cognitive anthropology (Fiske 1990, 1991, 1992, 2004a). In contrast to Wittgenstein's eventual theoretical nihilism, however, RMT is usually understood to be an attempt at formulating a generative grammar for social relations. Reflecting on why RMT is interpreted so differently from Wittgenstein's philosophy of logic, despite both being similar, even in very fundamental ways, will throw light on how the Second Theory can be understood in generative terms. RMT not only provides a model for theoretical development, it is an actual example of the application of calculi to spaces of social relations.

RMT assumes that the four scale types of Stevens (1946) are basic to social cognition. These four types are familiar from everyday life, illustrated in Table 1.

Scale types	**Examples**	**Examples**
Nominal	Pass versus fail	Hot versus cold
Ordinal	Student ranking	This is hotter than that
Interval	Letter grading	Centigrade
Ratio	Percentage grading	Kelvin

Table 1: Illustrations of Stevens' (1946) typology of scale types.

According to RMT, each basic mental model used in structuring social cognition strongly resembles one of the scale types. There are, thus, four basic forms of social interaction, one for each type of measurement scale.[7] Quoting the originator of RMT:

> Relational models theory is simple: People relate to each other in just four ways. Interaction can be structured with respect to (1) what people have in common, (2) ordered differences, (3) additive imbalances, or (4) ratios. When people focus on what they have in common, they are using a model we call Communal Sharing. When people construct some aspect of an interaction in terms of ordered differences, the model is Authority Ranking. When people attend to additive imbalances, they are framing the interaction in terms of the Equality Matching model. When they coordinate their actions according to proportions or rates, the model is Market Pricing. (Fiske 2004a: 3)

In Communal Sharing, people focus on what they have in common. This could be friendship, ethnicity, a history of suffering, romantic love, sharing food at the dinner table, etc. Fiske not only notes that nominal number assignments resemble Communal Sharing, he identifies Communal Sharing (CS) as a nominal scale:

> Roughly speaking, Communal Sharing is a kind of categorical (nominal) scaling, in that the only distinction that people make is of type or class: are two people of the same kind or different? Within the framework of the CS relationship, if two people belong to the same category (say, a family or ethnic group) then, with regard to the dimension that is communally organized, the people in that relationship are equivalent and undifferentiated.
> (Fiske 1991: 209)

An example of nominal scaling in measurement would be a questionnaire asking whether people smoke. Even though smoking is a matter of degree, this is ignored in nominal scaling. Either one belongs in the category of smoker or one does not. In Communal Sharing, likewise, one is either in the group or one is not. Shades of gray are not recognized.

Authority Ranking (AR) concerns ordered differences. Social units constitute a hierarchy. It resembles an ordinal scale, namely "a scale on which data are shown simply in accordance with some order, in the absence of appropriate units of measurement. For example, a squash ladder is an ordinal scale since one can say only that one competitor is better than another, but not by how much" (Borowski & Borwein 1991: 423). "Authority ranking is a linear ordering in which everyone's rank can be compared with everyone else's […]. Thus, the relations that are socially significant in an authority ranking relationship are similar to those that are specified by an ordinal scale" (Fiske 1992: 690).

In Equality Matching (EM), one maintains balance and corrects imbalances. Examples include the democratic principle of one vote per person, equal distribution of food in a school cafeteria, people taking turns, etc.

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[7] There is much controlled evidence supporting the claim that the scale types play a fundamental role in social cognition. A bibliography listing much of this work can be found at www.sscnet.ucla.edu/anthro/faculty/fiske/RM_PDFs/RM_bibliography.htm.

> Equality Matching relationships resemble an interval scale in that people can not only specify who owes what to whom, but also how much they owe. In order to determine whether they are even, people match or balance what each person has given and/or received, and they can assess how great the imbalance is. In EM, order is represented by the fact that owing someone two big favors is a greater debt (a greater asymmetry) than owing the person one small favor. But unlike an ordinal scale, in EM people take implicit account of how much they have coming to them. (Fiske 1991: 209)

In other words, EM presupposes something like a centigrade scale in which differences between people are measured using equal units.

In Market Pricing (MP) involves ratios or proportions, e.g. a judge finding the right level of punishment to fit a crime. Determining the right price for a commodity is perhaps a more obvious example. "The structure of MP […] closely resembles a ratio scale of measurement. A symbolic system of propositions and abstract logical operations makes possible complex manipulations of ratios" (Fiske 2004b: 126).

There is consilience between the calculus approach to non-verbal mental representation and RMT. In both, elementary forms of representation are defined in terms of measurement scales. Furthermore, the elementary relational models, according to RMT, can be combined to form compound models (Bolender 2011, Fiske 2011). This resembles the performance of operations on elementary propositions to form molecular propositions, as discussed in Section 3. The fact that there is strong empirical corroboration for RMT (Haslam 2004b) makes the consilience even more persuasive. The consilience looks like some degree of corroboration for the psychological reality of Wittgenstein's approach. The relational models of RMT look like a sub-set of the collection of possible calculi. Furthermore, just as elementary models are defined in terms of the four scale types, so the various Wittgensteinian calculi are as well. Framing the calculus approach in terms of Stevens' (1946) typology of scale types, a typology crucial to RMT, one can say that RMT is a fragment of a more general Wittgensteinian conception of how logical spaces are represented. Spaces of social possibility form a subset of logical spaces as such, on this approach.

The consilience runs even deeper than this, also embracing work on animal cognition. There is much evidence that measurement scaling is the proper way of conceiving how nonhuman animals represent states of affairs. In 1990, C. R. Gallistel published an introduction to an anthology of papers devoted to mental representation in non-human animals (a special issue of the journal *Cognition*). The papers addressed representations of space, time, number, categorization of stimuli, and social relations among conspecifics. Reflecting upon the data presented in the volume, Gallistel concluded that we should speak of representations in animal cognition in the same sense that one speaks of representation in mathematics, namely as a functioning isomorphism. He further concluded that in the discussion of isomorphism, one discerns measurement theory:

> Those familiar with the theory of measurement, as developed initially by Stevens (1946) and more recently by Krantz, Lute, Suppes, and Tversky (1971), will recognize the parallel between this use of representation and its use in measurement theory, where the principal task is to establish the

> necessary and sufficient empirical conditions for the existence of an isomorphism between a to-be-measured psychological variable (e.g., loudness) and some or all of the number field. The isomorphism depends on finding a suitable measurement procedure (scale), which maps from the psychological variable to numerical representatives thereof, and on the existence of a formal correspondence between combinatorial operations on the psychological variables (as manifest in, for example, "louder than" judgments) and numerical operations such as ">", "+", and "=". This correspondence permits one to draw valid inferences about the psychological variables from mathematical operations on their suitably determined numerical representatives. (Gallistel 1990: 1–2)

Later in his introduction, he also noted the relevance of an important advance in cognitive anthropology, namely Fiske's (1991) RMT (Gallistel 1990: 20). Specifically, he noted that the role of measurement scales in social cognition could be the tip of the iceberg, in that measurement scaling runs all the way down to the roots of mental representation.

There are deep similarities between Wittgenstein's Second Theory and RMT. Both view their subject matter as bundled into semi-independent subsystems. Furthermore, these sub-systems are, in at least some cases, constructed. This is especially clear in RMT, in which cultural variation is a factor in determining which construction of scales is applied to a type of social relation. For Wittgenstein, these were calculi. In Fiske's relational models theory, sociology is understood in terms of semi-independent psychological models. Wittgenstein understood each system as a construction of measurement scales, in the limiting case just a single scale. The same can be said of the social relational models of Fiske.

For Wittgenstein, logical relations within the system are to be understood in terms of mathematical operations. The transitivity of the greater-than/less-than relation of ordinal scaling would be an illustration of such a logical relation. Recursion also plays an analogous role in Wittgenstein and in Fiske.

> Among the Moose, a polygamous "nuclear family", a *zaka*, lives together and cultivates together, sharing stocks of food and eating together on a daily basis. Such a group is part of a compound (also *zaka*) that pools labor and food intermittently, occupying an enclosed living unit composed of one or more polygamous families. These compounds are grouped in larger unnamed communal groups that share a common grinding platform (*neere*) and greet outsiders ("*yeela*") when they first enter the area each day. People in this CS group routinely help each other with housebuilding, floor and yard pounding, beer brewing, and the like. These units are grouped in a named lineage neighborhood (*saka*) that is a communal group for other purposes, including giving and receiving wives, and making collective sacrifices to the ancestors. A set of neighborhoods comprise [*sic*] a village, which makes collective sacrifices to the earth for community fertility, rain, and protection from epidemics. The village (or sometimes the neighborhood) often pools labor to dig water catchment basins or wells. A set of villages makes up a named section with a loose sense of identity, and a few sections comprise a chieftainship under a paramount chief (*kombere*). The chieftainships together make up the Moose region. (Fiske 1991: 151)

For Fiske, social relations, relative to a given model, are to be understood in terms of mathematical operations (Fiske 1991: Ch. 9). It is reasonable to hold that the range of social cognition described by Fiske illustrates the application of logic to the social domain. In other words, the logic of Wittgenstein and the theory of Fiske stand in a genus/species relationship.

There is an historical irony here. For Fiske, recognition of the fundamental role of measurement scales in sociality led him to conclude that sociality is fundamentally simple. For Wittgenstein, however, the attempt to ground logic in measurement scales ended in frustration. Wittgenstein did not perceive an underlying unity in the types of measurements scaling. Whereas earlier, in *Tractatus* (Wittgenstein 1922: §§ 5.4541 & 6), Wittgenstein thought he had revealed a single simple underlying logical form in the appeal to truth functions, in his new appeal to measurement scales he could only perceive unstructured diversity. This ultimately led him to reject any attempt at theory, to view logical form, and even language as such, as a matter of loose family resemblances with no underlying essence (Wittgenstein 1974: 112–114, 2001: §§65–71).

In 1991, Fiske was in a good position to recognize a strong degree of unity and coherence among the types of measurement scales because of pioneering work in the theory of measurement conducted from the late 1940s through the 1980s. By extension, he was in a position to recognize a strong degree of unity and coherence in social cognition. Wittgenstein, by contrast, was pursuing his new theory of logic circa 1929, working without the benefit of these major advances. When Stevens published his watershed paper "On the Theory of Scales of Measurement" (Stevens 1946), Wittgenstein had already largely completed *Philosophical Investigations*. Not only was his anti-theoretical stance firmly entrenched by that time, there is no evidence that Wittgenstein, who died in 1951, was ever acquainted with Stevens' work. Furthermore, measurement theory continued to progress dramatically after 1951.

6. Logical Pluralism

The calculi approach is pluralistic. This is the case with regard to sociality specifically (Fiske) and with regard to logic quite generally (Wittgenstein). One can switch from one calculus to another in an effort to better conceptualize a domain of phenomena. It is perhaps even more evident that one will switch from one calculus to another according to the domain in question. There is empirical motivation for wanting an approach to natural logic with this sort of pluralism built into it.

More specifically, there is controlled evidence that people apply different logics to different subject matters. They will also sometimes shift from one logic to another for the same subject matter in an attempt to find the most suitable logic (Stenning & van Lambalgen 2008). On Stenning & van Lambalgen's interpretation of the data, the mind/brain imposes logical form on a task or puzzle, the form dictating the truth-preserving forms of inference. That one can shift between a fuzzy logic and a Boolean logic, according to the aims of one's inquiry, is perhaps obvious even before considering controlled evidence. In contexts in which it is useful to use terms such as 'frequently', 'slightly', etc., a fuzzy logic will be used. In the context of physics, one will often use a logic which is not fuzzy. Philosophers who discuss the identity conditions of the Ship of Theseus are, at least usually, assuming some kind of fuzzy logic. But this would not be the case if one were doing physics. "As far as the physicist is concerned, if you take out a nail, it's a new ship" (Chomsky 2012: 125). Even within a single field of endeavor, it may be rational to switch between logics, e.g. using a fuzzy logic to gauge symptoms ("severe headache", "frequent coughing"), and then a non-fuzzy logic to prescribe medication ("10 mg").

On this approach, it does not make sense to speak of a logic as being refuted. The question should be, rather: to what domain, if any, does a given logic apply? It is the assumption that a given logic applies to a given subject matter that is refuted, not the logic. Hence, the remarks of Danto (1988) and Hardin (1988) to the effect that experimentally induced experiences of reddish-green refute the sort of color logic found in, say, Wittgenstein's (1977) *Remarks on Colour*,[8] miss an important point. Danto and Hardin were justified in saying that such discoveries challenge philosophical arrogance and apriorism, and they may also have been correct in implying that Wittgenstein (or David Pears, whom Danto mentions without giving a full citation) were guilty of these. But the further implication that the observations (in e.g. Wittgenstein 1977) are in error is to overlook the fact that Wittgenstein's efforts can be interpreted as an investigation of *one possible logic* for making sense of color experience, presumably the one most commonly used. If one, in fact, experiences reddish-green in a laboratory setting, one can switch to a different color logic in order to accommodate the experience. This would be analogous to switching from Boolean logic to fuzzy logic when one discovers that the phenomena one assumed to be sharply discrete are actually rather amorphous. It also draws attention to the need for a generative approach to logic in which calculi are constructed as needed, just as social-relational models are constructed as needed.

Is there a space of possible logics, a kind of menu, from which one can choose? Stenning & van Lambalgen hesitate to say that there is:

> The approach to logic which we would like to advocate views logics from the point of view of possible syntactic and semantic choices, or what we will call parameter settings. This metaphor should not be taken too literally: we do not claim that a logic can be seen as a point in a well-behaved many dimensional space. (Stenning & van Lambalgen 2008: 25)

However, attempting to define such an all-encompassing space is worthwhile. Even if there is not such a space for all logics, there may be a space for a considerable number of them. To the extent that various logics can be defined in terms of a single space, one has achieved a degree of theoretical unification. Wittgenstein's Second Theory, as I argue in the next section, has the potential to provide a generative grammar of calculi, at least with regard to pre-verbal logics.

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[8] This is the sort of logic in which the mixing of complementary colors is impossible, contrary to the grammar of the calculus in other words.

7. Self-Organization and Generativity

The Second Theory, understood in terms of the four scale types, suggests clues as to the brain activity underlying the range of humanly accessible logical forms. The question is how the mind/brain explores such a space, or can construct logics defining such a space. The current proposal is that a calculus is composed by the mind/brain. Calculi are constructed so as to represent logics appropriate to various subject matters. (This does not cover all variations among logics, since it does not address operators; the paper is only addressing one type of variation —variation at the atomic level.) Given evidence that various logics serve as tools for different domains, if one logic does not function adequately, one will try another. That is, if one calculus does not prove useful, one avails oneself of another for the same subject matter. This is consistent with recent evidence that people have options among contrasting logical forms in performing reasoning tasks (Stenning & van Lambalgen 2008). The aim is to find a calculus with the same logical multiplicity as the relevant subject matter, like trying to find the right dimensionality for the area one wishes to map.

The calculi in question would be pre-linguistic, and it is thus not plausible to view them as the result of a Merge-like operation (Hauser et al. 2002, Berwick & Chomsky 2016). But this does not mean that they are not the result of a generative grammar, for there are generative grammars which are not Merge-like. There are, for example, regular grammars (Chomsky & Miller 1958). The grammar in question here would produce an unstructured set of scale tokens, i.e. it would essentially be a tokenization procedure. The result of the procedure would be something closely analogous to a numeration (Chomsky 1995), but there would be no reason to posit a Select procedure as each scale would be immediately assigned a semantic interpretation without any need for producing hierarchical structure. The semantic interpretation would be its mapping to the relevant dimension of the given space. The construction of such 'numerations' would involve processes closely analogous to finite-state automata (Uriagereka 2008), and hence would not contradict claims as to the human uniqueness of language.

But how would such a tokenization process work, physically speaking? I believe that we do have some clues as to what sort of neurological process underlies the construction of measurement scale tokens, and thus have clues as to how the brain constructs or defines logical forms. One begins to delve into these processes by understanding the role of admissible permutations in measurement theory. Such a discussion reveals formal properties of the scales which, in turn, suggests a role for self-organization in the neurological process of tokenization.

Each scale type is characterized by a set of admissible permutations (Narens 1981, 2002), i.e. transformations which preserve information (e.g., the transformation of Fahrenheit readings into Celsius readings, the transformation of prices as a result of inflation). An admissible transformation is a symmetry. Hence, each scale type is characterized in terms of a set of symmetries. The four types of scaling bear a striking resemblance to animal gaits (e.g., walk, trot, gallop) (Bolender 2010). Each scale type has a corresponding group of symmetries, just as each animal gait exhibits a corresponding group of spatiotemporal symmetries (Buono & Golubitsky 2001, Golubitsky & Stewart 2015). Given that much work has been done on the role of the central nervous system in gaits, specifically their symmetries, this provides a clue as to the neural origins of the scale types. In both cases, one finds a descending chain of subgroups. The symmetries of one gait will be a subset of the symmetries of a different gait; "transitions between gaits break symmetry" (Stewart & Golubitsky 1992: 202). Likewise, the symmetries of a ratio scale are a subset of the symmetries of the corresponding interval scale. The symmetries of the latter are a subset of the symmetries of the corresponding ordinal scale. Its symmetries, in turn, are a subset of those of the nominal scale (Stevens 1946). In other words, the permissible permutations of ratio scaling are a subset of the permissible permutations of interval scaling, etc.

In both cases, namely gaits and measurement scales, this resembles self-organization. An illustration would be the structure of a snowflake. The symmetries of the snowflake are a subset, specifically a subgroup, of the symmetries of the droplet of water from which it formed (Stewart & Golubitsky 1992). In self-organization, one finds a sequence of such symmetry breakdowns, i.e. a chain of descending subgroups. One finds such a sequence, for example, in the successive transitions from plasma to gas, from gas to liquid, and from liquid to solid. Spontaneous symmetry breaking is evidently the ultimate source of structure in the universe (Close 2001). Roughly speaking, things tend to crystallize.

There is, evidently, self-organization among neural firing patterns as well (Buzsáki 2006). Neural oscillations illustrate the point. According to the mathematical biologists Ian Stewart and Martin Golubitsky, oscillations, owing to entrainment, exhibit patterns which can exhibit symmetry breaking and symmetry restoration. The rhythm of firing in a neural network is a temporal symmetry. Through Hopf bifurcation, the firing can change from a relatively more symmetrical to a less symmetrical pattern:

> The simplest way to describe Hopf bifurcation is as the onset of a wobble. The idea is that the system is influenced by some external variable as well as undergoing its own internal dynamics. At first the system is in a steady state, and does nothing; but as the external variable changes, a very slight wobble develops, which then grows until it becomes pronounced.
>
> (Stewart & Golubitsky 1992: 66)

Being due to spontaneous symmetry breaking, the resulting oscillatory pattern need not be the same as the temporal symmetries of the input firings (Golubitsky & Stewart 2015). Hence, this is a source of variation internal to the system, but also distinct from genetic coding. The various possible gaits for a single species evidently illustrate this. A number of distinct gaits can be modeled in a single hypothetical neural network via spontaneous symmetry breakdowns (Golubitsky et al. 1998, Golubitsky & Stewart 2015). One can account for various gaits in an animal by positing a single central pattern generator of connected neurons rather than a different network for each gait. On this approach, gaits are not learned, but neither are they encoded in the genome. Spontaneous symmetry breaking provides the organism with a repertoire of possible gaits.

The analysis of gaits by means of Hopf bifucation began by noting the symmetry group for each gait, thus observing how they form a descending chain of subgroups. This corresponds to our current level of progress in understanding how the brain represents measurement scales. A descending subgroup chain defines human measurement capacities. A possible next step is to create a computer model of a pattern generator producing the specific symmetries of each scale type via self-organization. It is such neural circuitry which is postulated as providing the raw material for creating the various calculi, specifically tokens of the various types of scaling. One would have an account of the multiplicity of logics, in terms of symmetry breaking. One would also have an account of the underlying unity behind logics, or at least the preverbal ones: The breakdowns of symmetry occur in a single, closely-knit neural system.

Stenning & van Lambalgen (2008) review a number of controlled studies which, on their interpretation of the evidence, support the view that natural logic is task relative. That is, for example, one is presented with a domain of percepts, and the mind's first task is to arrive at a logic suitable for that domain. The point in adopting a logic is "to aid in 'going beyond the information given' when processing information" (Stenning & van Lambalgen 2008: 16). To take a familiar example, if one has adopted a logic for color phenomena in which red and green are mutually exclusive, from the presence of green throughout a space-time region one can infer the absence of any admixture of red in that region. If it is very hot throughout a region, one can immediately infer that it is not very cold anywhere within it. They argue that reasoning is not only a matter of reasoning with a logic but also a matter of reasoning to a logic appropriate for the domain in question.

One may wonder how one is supposed to understand reasoning to a logic without presupposing some logic or other. The question is somewhat vague, as the notion of logic itself is somewhat vague. I suggest that one can make some progress toward answering the question by having at hand a plausible conception of how a logic is constructed. Whether or not the method of construction is to count as a kind of meta-logic is a question which can be bracketed, as one attempts to gain a foothold in the enterprise of how logics are constructed. Perhaps once one has some sense of how logics are constructed, one will be in a better position to answer this question. Understanding how a logic is constructed requires an idea of the possible constituents of a logic, and how those constituents are combined to form a logic. Arriving at such an idea can be facilitated if one can take the range of possible logics and somehow resolve it into constituent sub-domains, and then proceed with the analysis of one of those sub-domains as a starting point.

Returning to the work of Stenning & van Lambalgen (2008), we begin to get some sense of how the pre-linguistic mental faculties could choose among logics so as to accommodate the range of possibilities for a given perceptual domain (this is to use the word 'choose' rather loosely). Specifically, there is a choice among different types of measurement scaling and among a different possible number of scales. The point would be to arrive at a calculus that is homomorphic to the space/domain in question; that is, which shares the same logical multiplicity. Even without appealing to the empirical work discussed and Stenning &

van Lambalgen, it is introspectively obvious that one could have to switch from one calculus to another in an attempt to find the right logical multiplicity for a perceptual domain. This is apparently the case given some perceptual conditions which, even though rather exotic, are nonetheless easily described.

Very early on in formulating his conception of calculi, Wittgenstein was acutely aware of difficulties in determining the number of measurement scales to be used in mirroring the logical form of a given space: "One's first thought is that it's incompatible for two colors to be in *one* place at the same time. The next is that two colors in one place simply combine to make another" (Wittgenstein 1975a: §76). For example, one's first thought is that it's incompatible for red and yellow to be in one place at the same time. The next is that red and yellow in one place simply combine to make orange. Given that one reading on a measurement scale logically excludes all other readings, red and yellow can only occupy the same space simultaneously if there are two scales in play: one measuring the amount of red, and another measuring the amount of yellow. Hence, the choice between logical rules in this sort of case is, at least partly, a choice regarding the number of scales to be used.

Remarkably, by the late 1930s, if not earlier, Wittgenstein firmly rejected the possibility that choosing among logics is an empirically sensitive matter:

> It may be said that we recognize orange as reddish yellow because orange paint comes from red and yellow paint. But mixing paints cannot in a sense show us that orange is reddish yellow. Why shouldn't there be a chemical reaction?
>
> You might say, "That is not what we mean by mixing. We mean you use a colour mixer top". But suppose that when you spun it with red and yellow discs, the velocity made it go black. Would you then be inclined to say that black is a blend of red and yellow?
>
> So we do not use experience as our criterion for orange being a blend of red and yellow. For even if the paints and the top gave black, we should not call black a mixture of red and yellow.
>
> (Wittgenstein 1975b: 233–234)

I suggest that we pause and reflect upon the difference between what would actually happen while observing a red/yellow spinner top versus the kind of spinner-top experience which Wittgenstein is asking us to imagine. In the case of an actual red/yellow spinner top, as the top gradually accelerates there would be a point at which one has an ambiguous sort of experience. It would be a point at which one would have some difficulty ascertaining the proper number of measurement scales to apply. For, at that moment, one could either interpret one's experience as being that of orange revealing itself as having red and yellow constituents, or one could interpret the experience as simply being of red and yellow in rapid alternation. It is at this moment that the mind struggles to find the right logic, specifically the right number of scales for the calculus. The logical question, at this point, reveals itself to be empirically sensitive. One looks for clues in the visual experience to find the right logical multiplicity for the calculus.

By contrast, the thought experiment which Wittgenstein describes does not involve this element of the experience forcing one to find or create the appropriate logic. There are two different ways of interpreting Wittgenstein's example.

One is that he is asking us to imagine the colors red and yellow of the top alternating faster and faster until at some point the top is suddenly perceived as being black. No transition. There is nothing, however, in this sort of experience that would challenge the observer to find the right number of scales for mirroring the logical multiplicity of the color black. The experience, rather, would simply be of two colors suddenly being replaced by a third color. The other possible interpretation of Wittgenstein's thought experiment is that as the top spins faster and faster, the alternating pattern of red and yellow shades into black. The experience, in that case, would be similar to the 'fade to black' effect in film editing. However, once again, there is nothing in the experience that would challenge the observer to find the right number of scales to reflect the logical multiplicity of the color black. By contrast, in the realistic case in which the ever more rapid alternation of red and yellow merges into orange, there is a point at which the mind is challenged to find the right multiplicity. This is because, the red–yellow alternation is not simply fading into orange. There is, rather, the curious effect of the red–yellow alternation reaching a point at which the perceiver begins to see the alternation as a kind of orange. The observer can either interpret what they see as rapid alternation of red and yellow, or as orange with its internal structure laid bare. There is an in-between point at which the observer has some trouble judging which logic to use, in other words how many dimensions the calculus should have. The observer is experiencing some pressure to recognize an extra dimension (scale) so as to accommodate the apparent structure of orange. In other words, there is a transitional point at which the observer actually has the experience of orange as being constituted by red and yellow. There is nothing like this for the transition which Wittgenstein described from yellow/red into black.

Furthermore, this transitional stage is one in which the experience itself could force the observer to add a scale to the relevant calculus, thus resulting in a distinct calculus. It shows an experience forcing a change in logic.

8. Summary

In early Intermediate Wittgenstein, we find the following conception of mental representation: There are calculi which function to represent and capture logical relations in relative independence of one another. Each calculus represents a logical space, a range of conceptual possibilities, partly by reason of being isomorphic with the pertinent space. Some of these logical spaces may be mental constructions, while others may not be. The outputs of calculi can be combined using a recursive operation (Wittgenstein 1922: §5.2521) which serves as a point of connection between the various calculi. In terms of cognitive science, Chomsky's (1995) Merge operation is one possibility. A given pre-linguistic calculus is constructed from measurement scales. Given later developments in measurement theory, we can say, in hindsight, that there is the sort of beauty in these calculi evidencing self-organization. Hence, some properties of the calculi may 'come for free' in a manner similar to how economy conditions in syntax 'come for free', if they are indeed the result of self-organization.

Aiming to use Wittgenstein's Second Theory to further develop an account of semantics within the biolinguistic framework suggests a number of more specific projects. One such project is to use advances in measurement theory to better understand the range of possible calculi. For example, the possible scales of measurement are not limited to the four types discussed in Stevens (1946). There is also discrete interval scaling (Narens & Luce 1986). But note that all the possible types of scaling belong to the descending subgroup chain discussed earlier. Discrete interval scaling, for example, is located between interval scaling and ratio scaling, in the subgroup chain. Mention of the descending subgroup chain brings us to another project, namely understanding how the mind/brain constructs calculi in terms of spontaneous symmetry breakdowns in neural activity. Much brain activity is evidently the result of self-organization (Buzsáki 2006), and one wants to understand how the role of measurement scales in the construction of calculi is the result of such self-organizing activity, and precisely which self-organizing activity in the brain is in question (Bolender 2010).

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★ FORUM ★

Merge and Labeling as Descent with Modification of Categorization: A Neo-Lennebergian Approach

Koji Hoshi

1. Introduction

The problem concerning the emergence of the faculty of language (FL) in our species is sometimes referred to as *Darwin's Problem* in the literature, as stated in (1) (see e.g. Boeckx 2009 and Hornstein 2009):

(1) *Darwin's Problem*
How did the faculty of language emerge in our species?

Regarding the nature of FL and its evolution, Hornstein remarks the following:[1]

> [I]t is of recent evolutionary vintage. A common assumption is that language arose in humans in roughly the last 50,000–100,000 years. This is very rapid in evolutionary terms. I suggest the following picture: FL is the product of (at most) one (or two) evolutionary innovations which, when combined with cognitive resources available before the changes that led to language, delivers FL. (Hornstein 2009: 4)

Without touching upon the important issue on the evolutionary vintage of the emergence of FL in our species in the following discussion, I will only focus

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[1] Berwick & Chomsky (2016) speculate that FL emerged between 200,000 and 60,000 years ago in light of recent archaeological/paleoanthropological evidence. Ike-uchi (2016), on the other hand, makes a more specific claim that FL emerged as early as 130,000 to 150,000 years ago on the basis of recent archaeological/paleoanthropological and genetic evidence.

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on a possible origin of the syntactic structure-building operation Merge and its related labeling operation in the evolution of FL. Particularly, I will address what sort of Darwinian descent with modification would be at least theoretically conceivable on the basis of a biologically plausible precursor in the emergence of Merge and its related labeling.

At the outset, I would like to emphasize that the current contribution is intended as more of an opinion piece rather than a research article. As such, since I will propose a particular hypothesis on the origin of Merge and its related labeling in the evolution of FL purely at a theoretical level, it remains to be tested empirically in the field of comparative cognitive neurobiology in the future (see Fitch 2011 for the significance of the role of comparative research in testing evolutionary hypotheses).

With this caveat in mind, I would like to suggest re-visiting Lenneberg's (1967) conjecture on the evolution of the capacity for language as cited below as a point of departure, while revising it from the perspective of modern linguistic theorizing to give it a new lease of life. Lenneberg makes the following conjecture on the relation between categorization and the cognitive function underlying language in the context of evolution of the capacity for language (see Bickerton 1990: Chap. 4 for very informative discussion on categorization in animals; see also papers in Zentall & Smeets 1996 for more recent discussion on categorization in humans and animals):

(2) *Lenneberg's Conjecture on the Evolution of the Capacity for Language*

> The cognitive function underlying language consists of an adaptation of a ubiquitous process (among vertebrates) of categorization and extraction of similarities. The perception and production of language may be reduced on all levels to categorization processes, including the subsuming of narrow categories under more comprehensive ones and the subdivision of comprehensive categories into more specific ones. The extraction of similarities does not only operate upon physical stimuli but also upon categories of underlying structural schemata.[2] (Lenneberg 1967: 374)

The organization of this opinion piece is as follows. Section 2 compares categorization and Merge/labeling in an attempt to highlight similarities and differences between the two. Section 3 proposes a neo-Lennebergian approach to the origin of Merge and its related labeling in the evolution of FL. Section 4 concludes this work with some remarks.

2. Comparison of Categorization and Merge/Labeling

2.1. Two Modes of Categorization

In properly comparing categorization with Merge/labeling, it is of necessity to differentiate two modes of categorization, as discussed in Lenneberg (1967).

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[2] In connection with (2), it is instructive to note that Lenneberg (1967: 72) points out that "[t]his capacity may be due to structural innovations on a molecular level". Thus, he had already conceived the relevant "adaptation" in (2) as due to some structural changes on a DNA molecular level.

Crucially, Lenneberg (1967) notes that there are two modes of categorization, namely differentiation and interrelation, as shown in (3):

(3) *Two Modes of Categorization: Differentiation & Interrelation*

$$\text{Categorization} \begin{cases} \text{Differentiation} \\ \text{Interrelation} \end{cases}$$

As an illustration, let us consider a simple hypothetical situation:

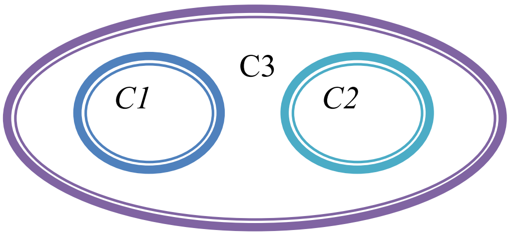

Figure 1: Differentiational Categorization vs. Interrelational Categorization

Suppose that there are two sub-sets with the category labels C1 and C2, respectively, and there is one super-set with the category label C3.[3] In *Figure 1*, if the comprehensive super-set C3 has been sub-divided, or *differentiated*, into the two sub-sets C1 and C2 by categorization, the differentiational mode of categorization is at work; whereas, if the two narrower sets C1 and C2 have been subsumed, or *interrelated*, under the super-set C3 by categorization, the interrelational mode of categorization is in operation. Therefore, the two modes of categorization reflect two possible 'directions' of the operation of categorization.[4]

2.2. *Interrelational Categorization vs. Merge/Labeling*

Ever since Chomsky (1995), the formulation of Merge has been reduced to the bare minimum, with the simplest form as stated in (4) (e.g., Chomsky 2013, 2015):

(4) Merge (X, Y) = {X, Y} (X, Y is either a lexical item or a syntactic object (SO) already formed by Merge)

When X and Y are independent of each other and do not contain each other, such Merge is called 'external Merge'. On the other hand, when either X or Y is part of the other, such Merge is referred to as 'internal Merge'. It is not the case that

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[3] 'Labels' of categories are brain-internal representations, which can be regarded as concepts in the sense of Carey (2009). On the origin of concepts, see Carey (2009) for comprehensive, in-depth discussion.

[4] Differentiational categorization seems to be relevant to *Disintegration Hypothesis* (DH) proposed by Fujita & Fujita (2016) in accounting for the emergence of human lexicon with lexical items (both lexical and functional category) in the evolution of human language. Though dealing with the issue of evolution of human lexicon is one of the most important agenda in biolinguistics, I will not address differentiational categorization in this opinion piece (see also Lenneberg 1975 for insightful discussion on the notion of differentiation in the development of human lexicon).

there are two types of Merge. They are just two different modes of a single operation of Merge (see Chomsky 2004). Labeling of SOs (= set-structures) formed by Merge is the process of providing the information as to what kind of object such set-structures are in order for them to be interpreted properly at the conceptual-intentional (C-I) and sensorimotor (SM) interfaces (see Chomsky 2013, 2015). Note that the operation of Merge *per se* has nothing to do with labeling.

Considering the similar combinatorial property of Merge and interrelational categorization, I will take it that the proper comparison should be between Merge and interrelational categorization rather than differentiational categorization.[5] For expository purposes, let us define interrelational categorization as follows as a first approximation (see Cohen & Lefebvre 2005 for in-depth overview and discussion on categorization in a variety of cognitive domains). Suppose that κ is a label for interrelational categorization, then it can be taken as a sort of characteristic function that applies to any element indicated by x that either 'satisfies' the label or not, as defined in (5):[6]

(5) $$\kappa(x) = \begin{cases} 1 \text{ if } x \in \kappa \\ 0 \text{ if } x \notin \kappa \end{cases}$$

I will name the operation for interrelational categorization *IntCat* for expository purposes and formulate it as an unordered set-formation under a particular label specified by κ as follows:

(6) $$IntCat^{\kappa}(x_1, \ldots, x_n) = \{x_1, \ldots, x_n\}\ (x_i \in \kappa,\ 1 \leq i \leq n)$$

(x_i is a target element for interrelational categorization and κ is a label, where the sequence in the set uniformly contains either a series of entities or a series of sets as the value of x_i)

Next, let us take a close look at the similarities and differences between Merge and IntCat with respect to their crucial properties, which are summarized in Table 1:

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[5] Thornton (2016) discusses the case of what he calls *hierarchic concept-combination* (HCC) in connection with Merge, such as a family that consists of a mother and a child with the concept *family* serving as the "accommodating concept for providing the root" for the hierarchic concept [**family** mother child] in his notation. One possible reinterpretation of HCC is that it is a particular case of interrelational categorization in the C-I system, in which the label of the set for the categorization here is something like "concepts that make up the concepts of *family*". Note that, unlike Merge, which is binary, interrelational categorization is not limited to binarity, in principle, which is exactly needed for HCC in general as well, as shown by the possible hierarchic concept [**family** mother father child pet dog], etc.

[6] Here, I am making a sort of idealization with respect to the characteristic function in question for categorization. In reality, as is well-known in the fields of psychology and cognitive linguistics, membership determination/identification for categories on the basis of extraction of similarities among set members is nuanced and complicated (see among others Rosch 1973, Lakoff 1987, and Taylor 2003).

	Merge	IntCat
(a) *input cardinality*	n = 2	n ≥ 2
(b) *output cardinality*	n = 1	n = 1
(c) *output set*	unordered set	unordered set
(d) *labeling*	label-free	labeled
(e) *recursivity*	fully recursive	partially recursive
(f) *availability*	both external and internal	external only

Table 1: Crucial Properties of Merge and IntCat

First, concerning input cardinality, while Merge is standardly taken as binary, IntCat is equal to or more than binary. Note that IntCat *interrelates* target objects, so the input cardinality should be minimally 2 by nature. Second, as for output cardinality, both of them are unary. Third, both Merge and IntCat form an unordered set as output. Fourth, Merge is label-free, whereas IntCat is labeled due to the very nature of categorization. Fifth, Merge is fully recursive, while IntCat is only partially recursive (see the discussion below; see also Watumull *et al.* 2014 for a thorough discussion on recursion in general). Finally, in principle, Merge permits both an 'external' and an 'internal' option, IntCat only allows for an 'external' option, excluding an 'internal' one (see the discussion below).

With respect to the first point, as Fujita (2017) rightly points out, appealing to the third factor such as the principle of efficient computation/minimal computation (Chomsky 2005) to account for the binarity of Merge (Chomsky 2008) is not convincing enough. This is because nothing would prevent the third factor from applying to other cognitive domains equally as well and the combinatorial operations in the other cognitive domains would also be strictly binary, given that the third factor is not specific to FL (Chomsky 2005). Similarly, a reviewer for *Biolinguistics* also correctly warns me that, given that the third factor is a general one not limited to language, it cannot account for why IntCat is not strictly binary, too. Therefore, there must be a principled reason for the binarity of Merge within the nature of FL itself, independent of the third factor.

One possibility suggested by Fujita (2017) is that binary branching structure is less costly than multiary branching structure in determining linear ordering of elements by linearizing hierarchical syntactic structures along the line of Linear Correspondence Axiom (LCA) interpreted as a linearization principle (see Kayne 1994, Chomsky 1995, Moro 2000). If this is basically on the right track, then it must be the case that linearization of hierarchical syntactic structures is always required in FL even when articulation of the linearized elements by speech or sign is not actually occurring externally in an individual, as in silent monologues.

In order to understand the fifth point, it is first necessary to consider the final point: the asymmetry of external/internal availability between Merge and IntCat. While Merge permits both external and internal option, IntCat only allows for external option. Note that to the extent that a label for IntCat is determined, you could put any number of relevant independent elements into the category set by interrelating them (= external option). What would the putative internal option of IntCat be like?

Here, terminological clarification seems to be required in order to avoid confusion in the following discussion. I will use the names "lemon", "tangerine", "citrus fruits", and so on as labels for categories, just for ease of exposition. Strictly speaking, I distinguish between *labeling of categories* and *naming of categories*. The former refers to identification/specification of categories by some brain-internal representations corresponding to 'concepts' (see fn. 3). This is what I intend to mean when I informally use "lemon", "tangerine", and "citrus fruits" in what follows. On the other hand, the latter refers to pairing of labels of categories with some brain-internal 'forms' for externalization such as particular phonological representations of sound sequences in speech or signs in sign language in the case of human language, in the sense of Saussure (1916) (see also Bouchard 2013 for interesting discussion on Saussurean signs in the context of evolution of language). Alarm calls in animal communication systems may be regarded as a kind of 'naming' of categories (= proto-concepts in the sense of Hurford 2007) in stimulus-response behavior (see e.g. Bickerton 1990 for discussion on the different nature of labeling of categories between animal communication systems and human language).

Now, imagine a concrete interrelational categorization case. Suppose you have a category with the label "lemon" and another category with the label "tangerine". Next, you interrelate the two category sets under a super-category set with the label "citrus fruits". Suppose further that you have a category with the label "apple" and another category with the label "pear". Next, you interrelate the two category sets under a super-category set with the label "pome fruits". Furthermore, suppose that you interrelate the two super-sets with the labels "citrus fruits" and "pome fruits" to form a more inclusive super-set, presumably with the label "fruits". Now, you 'extract' the "lemon" category set from the "citrus fruits" category set by the putative internal option of IntCat and try to categorize the extracted 'copy' of the "lemon" category set together with the inclusive super-set containing the "citrus fruits" category set and the "pome fruits" category set. Is this kind of operation possible in the first place? I do not think so. Notice that, because of the 'status difference' between the extracted "lemon" subset and the inclusive super-set containing the "citrus fruits" category set and the "pome fruits" category set, in principle, you could not possibly determine any appropriate label for the whole would-be category set created by such putative internal option of IntCat. Hence, I conclude that an internal option of IntCat is not available in general. By contrast, Merge freely enjoys an internal option (= internal Merge) because there would be no 'status difference' between internally Merged X and Y due to lack of labeling in the operation of Merge *per se*.

Accordingly, and with regard to the fifth point, since Merge permits both external and internal options, it is fully recursive. On the other hand, since IntCat only allows for the external option in that it can only take independent category sets or independently created super-category sets as its input, it is partially recursive.

2.3. *More on Labeling for Interrelational Categorization (IntCat) and Merge*

A reviewer points out that labeling of categorization, or categorial labeling, is inherently exocentric, while syntactic labeling is endocentric as well as exocentric. With this remark as a point of departure, it seems to be worthwhile to closely examine the nature of labeling for IntCat and Merge as well as its relation to the notions of endocentricity and exocentricity commonly utilized in linguistics in order to build the foundation for the hypothesis on the emergence of Merge/labeling that I will propose in the next section.

Let us first take stock of the nature of labeling for interrelational categorization. Notice that, in general, labeling of categories comes with two types:[7] One category labeling pattern is such that the label of a category set is determined, more or less, on the basis of some inherent relevant property shared by all the members in the set. Another category labeling pattern, on the other hand, corresponds to the case where the label of a category set is not specified by such an inherent common property of all the members but is supplied by some external/contextual condition. Thus, the category set {John, Bill, Tom, …} with the label, say, 'boy' illustrates the former, while the category set {scissors, a German dictionary, a coffee cup, a bill, a printer, …} with the label, say, 'what exists on that desk' represents the latter. In either case the labeling pattern for categorization is 'exocentric' in that there is no single element that can serve as the 'head' for determining the label of the whole category set.

Now, what about labeling for Merge in syntax? Although Merge *per se* is independent of labeling, it typically involves two kinds of unordered set-structure: {H, XP} and {XP, YP} (e.g. Chomsky 2013, 2015).[8] In the case of {H, XP}, where a lexical item is merged as a head H with a syntactically complex object XP already formed by Merge independently (e.g., *eat* is merged with *that apple* to form {*eat* {*that apple*}}).[9] In the tradition of generative grammar (Chomsky 1970), it has been standardly assumed that the syntactic structure corresponding to {H, XP} is 'endocentric' because it is 'headed' by the lexical item H in it (e.g., the verb phrase *eat that apple* is endocentic due to its being headed by the verb *eat*).

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[7] I owe the observation that, generally, there are two modes of labeling for category sets to Satoshi Oku (personal communication).

[8] Chomsky (2013, 2015) proposes the following *labeling algorithm* (LA) that applies to set-structures created by Merge:

(i) {H, XP}
➔ Label of {H, XP} is H.

(ii) {<XP>, YP} (without agreement; either XP or YP in the set will undergo internal Merge)
➔ Label of {<XP>, YP} is Y.

(iii) {XP, YP} (with agreement between X(P) and Y(P) in the set)
➔ Label of {XP, YP} is <ϕ, ϕ> or <Q, Q>, depending on the agreement relation.

(i) illustrates cases of categorial labels of the head elements such as *v, n, a, p,* D, T, C in a head–complement structure. (ii) illustrates cases of categorial labels for the subject–predicate construction {<DP/*n*P>, *v*P} (in English) and for the intermediate landing site {*Wh*-DP/*n*P, CP} of successive-cyclic *wh*-movement. (iii) illustrates cases of non-categorial agreement-based labels for the final landing-site {Wh-DP/*n*P, CP} of successive-cyclic *wh*-movement.

[9] In what follows, I will abbreviate set representations for SOs by ignoring some internal sets just for expository simplicity.

The question that I would like to pose at this juncture is whether there is an alternative view to this standard doctrine. Note that the unordered set formed by Merge has two members, H and XP (such as *eat* and *that apple*), which do not share any inherent common property. Therefore, it may be taken on a par with the category set {scissors, a German dictionary, a coffee cup, a bill, a printer, …} with the label 'what exists on that desk,' which is provided externally/ contextually. Let us take {*eat* {*that apple*}} as a concrete example.[10] If the similarity is close enough, then you might be able to hypothesize that the label for {*eat* {*that apple*}} is in fact supplied externally/contextually, such as 'what makes up an event(uality),' within a larger configurational context with functional projections including tense and force information.[11] This assumption seems to be quite natural, provided that at least the tense element semantically/conceptually necessitates the presence of an event(uality). If this were to be the case, the {H, XP} configuration would be 'exocentric' in that its labeling is determined externally/ contextually, much the same as the case of labeling of categorization. At the same time, it appears to be 'endocentric' in that it contains an event(uality)-denoting element *eat,* which would be compatible, as a 'prominent element', with the externally/contextually supplied label 'what makes up an event(uality)' of the whole set {*eat* {*that apple*}}. How could we make sense of this situation? One possibility is to assume that the set {*eat* {*that apple*}} is in fact solely exocentric and the label 'what makes up an event(uality)' of the set semantically/conceptually requires an event(uality)-denoting element like *eat* as its obligatory pivotal member, which is intuitively taken as the 'head' of the set. If this reasoning holds, 'endocentricity' in the {H, XP} structure might be an epiphenomenon.

Next, consider the exemplar exocentric structure of {XP, YP}, where two SOs of the same 'size' status are merged. This case may be regarded as comparable with the category set {John, Bill, Tom, …} with the label 'boy,' mentioned above. Let us take {{*the boy*} {*will eat that apple*}} as a concrete example, where DP {*the boy*} has been internally merged with TP {*will eat that apple*}. Here, the two elements, the DP {*the boy*} and the TP {*will eat that apple*}, share an inherent common property of ϕ-features for agreement, and the label <ϕ, ϕ> (Chomsky 2013, 2015) will be attached to the whole set {{*the boy*} {*will eat that apple*}}, just like the shared inherent common property 'boy' is attached to the category set {John, Bill, Tom, …}.

If this line of analysis is on the right track, it might be reasonable to think that not only categorial labeling but also syntactic labeling is invariably exocentric, contrary to the standard assumption. The conclusion on the parallelism between categorial labeling and syntactic labeling is crucial in putting forth a new proposal on the origin of Merge/labeling in the evolution of FL.

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[10] Strictly speaking, it is currently assumed in the minimalist program that the underlying structure for *eat that apple* should look like {*v** {√*EAT* {*that apple*}}}, where *v** is an abstract causative verb, to which the root element √EAT will be moved (see Chomsky 2013, 2015). I will abstract away from this detail in the text.

[11] In fact, Lenneberg (1967, 1975) proposes that the specification of syntactic categories is determined on the basis of modes of functioning within a larger context of syntactic structure. Furthermore, Leivada (2017) argues that there are no inherent syntactic categorial labels such as noun and verb in human language on the basis of Lenneberg (1967, 1975) and Barner & Bale (2002).

3. A Neo-Lennebergian Approach to the Origin of Merge/Labeling

In view of the similarities and differences between Merge and IntCat in *Table 1* and the similar nature of labeling for the two cognitive processes, I will propose the following hypothesis in (7) on the origin of Merge and its related labeling in the biological evolution of FL by re-interpreting Lenneberg's (1967) conjecture in (2) in the light of the discussion in section 2:

(7) *On the Origin of Merge and Its Related Labeling*

In the event of biological evolution of FL, Merge (= set-formation) derived from interrelational categorization IntCat (= labeling + set-formation) as descent with a certain modification, while preserving the capacity for IntCat *per se*. The modification in the brain of our ancestor that underwent a relevant genetic mutation, accompanied by its adaptive value, was such that Merge came into existence as a result of detachment of the set-formation component from IntCat, hence separating it from labeling, while the remaining labeling component came to be employed for labeling SOs formed by Merge.[12]

The modification in question can be represented as follows in *Figure 2*:

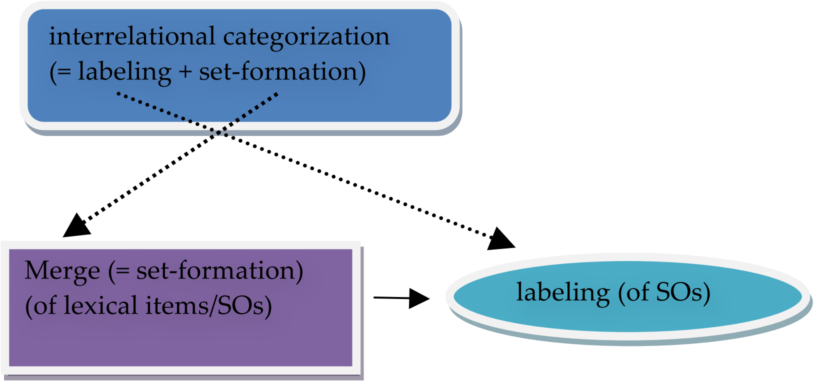

Figure 2: Merge & Labeling as Descent with Modification of Interrelational Categorization

Notice that even if Merge and its related labeling are originally due to the two components of interrelational categorization, both of them are now adapted to the use in the faculty of language (FL) in human language: they have to apply to lexical items (= conceptual atoms) and/or SOs formed by Merge. Furthermore,

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[12] It has been widely discussed in the literature that natural language syntax and action grammar (motor planning) are parallel in that both involve hierarchical structures of some sort (see Greenfield 1998, Jackendoff 2007, Fujita 2009, Pulvermüller 2014, Stout 2010, Arbib 2012, Knott 2012, among others, but e.g. Moro 2014 for a different view). Since (interrelational) categorization is at work both in the sensori-motor domain and in the conceptual-intentional domain (e.g., Lenneberg 1967), one possibility is that those hierarchical structures claimed in action grammar might well be characterizable in terms of (interrelational) categorization, from which Merge was derived, if my hypothesis in the text is on the right track. Whether this conjecture is valid or not should be tested empirically, which I have to leave to future research.

upon the emergence of Merge, lexical items as conceptual atoms must have come to be combined by Merge to create various SOs, which in turn served as complex labels (e.g., '*gifted pre-school child who is good at playing chess*') for further categorization (both differentiational and interrelational) in human cognition. I surmise that this led to "the qualitative distinctness of both modern symbolic cognition and language" (Tattersall 2017: 64).

Now, how would the pertinent modification to yield Merge and its related labeling from interrelational categorization have possibly been implemented biologically in the course of evolution of our species? Given the fact that the ability of (both interrelational and differentiational) categorization has continued to exist in our species, even if Merge and its related labeling were derived in the course of phylogeny as decent with modification of interrelational categorization, both Merge/labeling and (interrelational) categorization have to develop biologically in the course of ontogeny as well. Then, what kind of biological evolutionary story would be the most plausible?

In this connection, it is very informative to note the well-established fact on biological evolution that Bouchard (2013) touches on in the following remark:

> Biological systems evolve through a mix of introducing redundant duplication in the organism's structure and losing bits of structure. Duplication provides a safety net for the system, but it also provides an opportunity for change. A gene optimized for a particular function may remain stable, but its copy may undergo random variations which turn out to be advantageous for adaptation and give rise to a new function (Gould & Lewontin 1979, Dawkins 1986, Sterelny 2001, to name but a few). (Bouchard 2013: 53)

As concisely put in this quote, it is well-known in biology that gene duplication permits one copy of a duplicated DNA region to become free from selectional pressures and to undergo genetic mutation at random (e.g., Ohno 1970, Zhang 2003). Thus, one possibility for the descent with modification in (7)/*Figure 2* is that gene duplication in either coding or noncoding DNA areas played a role for the presumed genetic mutation for yielding Merge/labeling out of interrelational categorization in the evolution of FL in our species.

While it is true that genomics, including research on the areas of chromosome 7, which is related to language, has made a significant progress so that we can address specific genes (e.g., Benítez-Burraco 2013, Boeckx & Benítez-Burraco 2014a, 2014b, Fisher & Vernes 2015), in order to test my hypothesis in (7)/*Figure 2* empirically and eventually pin down the relevant genes related to (interrelational) categorization, Merge, and labeling, collaborative in-depth investigation into the genetic underpinnings of (interrelational) categorization among vertebrates, particularly primates, would be clearly called for in comparative genomics and comparative neuroscience (see e.g. Fitch 2005, 2017 for detailed discussion on the significance of empirical and interdisciplinary comparative approaches to the study of language evolution), given that categorization can be ubiquitously observed among vertebrates (e.g., Lenneberg 1967).

Also equally important to empirically corroborating my hypothesis on the origin of Merge/labeling in FL is to construct a linking theory at the dynome-level, accounting for how (interrelational) categorization (= labeling + set-formation) and Merge (= set-formation) and its related labeling are implemented in terms of brain oscillations (see Murphy 2015, 2016, Benítez-Burraco & Murphy 2016, and Murphy & Benítez-Burraco 2016, among others, for discussion on the relation between brain oscillations and language). It is hoped that future research would shed a new light on this issue.

Finally, let me make a brief remark on recursivity of Merge. With respect to recursivity in Merge, there has been a controversy in the literature over the continuous view (Pinker & Jackendoff 2005, Jackendoff & Pinker 2005) and the discontinuous view (Hauser *et al.* 2002, Fitch *et al.* 2005). To the extent that Merge as a set-formation operation derived from the set-formation component of interrelational categorization as descent with Darwinian modification, with the property of full recursivity in Merge and that of partial recursivity in interrelational categorization, as argued in this opinion piece, the property of recursivity should not completely be a novelty in Merge.

4. Concluding Remarks

In this opinion piece, I addressed *Darwin's Problem* as it is concerned with the origin of Merge and its related labeling in the evolution of faculty of language (FL) in our species, and proposed a neo-Lennebergian approach to this issue by up-dating Lenneberg's (1967) conjecture on the evolution of the capacity for language. Specifically, I hypothesized a possibility that Merge and its related labeling in the FL in our species derived as Darwinian descent with modification of (interrelational) categorization, which can be observed ubiquitously among vertebrates, including primates (e.g., Lenneberg 1967).

Given that both the ability of interrelational categorization and that of Merge/labeling will develop in a child ontogenetically, the presumed genetic change behind such phylogenetic modification, which was inherited from our pre-FL ancestor as part of our species' genome, must have been responsible for creating the ability of Merge/labeling out of that of interrelational categorization, while preserving the latter in our species. I speculated that some kind of gene duplication in biological evolution must have been at work in the derivation of Merge/labeling.

Finally, I would like to touch upon the relation between language evolution and language disorders. As clearly demonstrated in Benítez-Burraco & Boeckx (2014) and Benítez-Burraco & Murphy (2016), the issues of language evolution and language disorders are intimately related with each other (see also Lenneberg 1967: Chap. 9). While disentangling and solving various issues in language evolution is without doubt an honorable enterprise in and of itself, I strongly believe that the outcome of such investigation should not be confined to the field of language evolution proper, but should be usefully and systematically put to use in the field of medicine as well as that of clinical linguistics (see Benítez-Burraco 2016 for review of the latter) for making effective medical intervention for language disorders.

Although the complicated aspects of language evolution obviously demands interdisciplinary investigation based on various methods and approaches, I speculate that research results in the study of language evolution at the dynome and genome level, for instance, should offer useful and valuable hints for developing effective protocols of medical intervention for language disorders.

If a language disorder is not clearly associated with any particular gene(s) but is clearly linked with oscillopathy as reflected in electroencephalographic (EEG) abnormalities (e.g., Deonna & Roulet-Perez 2016), then the proper medical intervention for such cases would be based on the combination of medication controlling synaptic transmission with neuromodulation techniques such as transcranial direct current stimulation (tDCS), which ideally should take place during the critical period of language development (see e.g. Hoshi & Miyazato 2016, Hoshi 2017 for a proposal of medical treatment protocol for patients with child aphasia of epileptic origin).

On the other hand, if a language disorder is identified as being linked to (a) particular gene(s) (see e.g. Kambanaros & Grohmann 2017, Benítez-Burraco *et al.* 2018, and references therein), then the ultimate medical intervention for such cases might be administered possibly by regenerative medical techniques using, for instance, induced pluripotent stem (iPS) cells (e.g., Takahashi *et al.* 2007), though this surely should be cautiously examined further.

Consequently, we should recall that, regardless of whether language disorders are of oscillatory origin or of genetic origin, there are always remaining future hopes for discovering methods of recovery from those language disorders, if new findings in the filed of language evolution could be effectively and systematically utilized in the field of medicine. Thus, prompt interdisciplinary endeavor in the light of biolinguistic perspectives on medicine is highly expected for investigating possibilities to "cure" these apparently "incurable disabilities", as Lenneberg (1967) hoped to pursue (see Hoshi 2017).

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ϕ-Features in Animal Cognition

Chris Golston

This paper argues that the core ϕ-features behind grammatical person, number, and gender are widely used in animal cognition and are in no way limited to humans or to communication. Based on this, it is hypothesized (i) that the semantics behind ϕ-features were fixed long before primates evolved, (ii) that most go back as far as far as vertebrates, and (iii) that some are shared with insects and plants.

Keywords: animal cognition; gender; number; person

1. Introduction

Bickerton claims that language is ill understood as a communication system:

> [F]or most of us, language seems primarily, or even exclusively, to be a means of communication. But it is not even primarily a means of communication. Rather, it is a system of representation, a means for sorting and manipulating the plethora of information that deluges us throughout our waking life. (Bickerton 1990: 5)

As Berwick & Chomsky (2016: 102) put it recently "language is fundamentally a system of thought". Since much of our system of representation seems to be shared with other animals, it has been argued that we should "search for the ancestry of language not in prior systems of animal communication, but in prior representational systems" (Bickerton 1990: 23).

In support of this, I provide evidence that all the major ϕ-features are shared with primates, most with vertebrates, and some with plants; and that there are no ϕ-features whose semantics are unique to humans. Specifically human categories, including all things that vary across human cultures, seem to

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be expressed by nouns, verbs, and adjectives, never by function words or affixes. Specifically, I hypothesize:

(1) The semantics of grammatical categories are not unique to humans.

But this is a much broader claim than can be argued for here, so I limit the present work to a subset of what Zwicky calls direct features, those "associated directly with prototypical, or default, semantics" (Zwicky 1992: 378). I leave aside his indirect features—case, declension, conjugation, and finiteness—which do not seem to have any analogues in animal cognition and are probably unique to grammar; I focus on the features behind grammatical person, number, and gender. I present evidence elsewhere for the use in animal cognition of the verbal categories tense, mood, and aspect, and for the use of θ-roles (Golston 2018), though the argument here for ϕ-features stands alone and in no way relies on those efforts, or vice versa.

The specific features I will be concerned with here comprise the traditional categories of person, number, and gender:

(2) *ϕ-features we share with other animals*

Person:	*first, second, third*
Number:	*singular, dual, plural; comparative, superlative*
Gender:	*masculine, feminine, neuter; animate*

These constitute the ϕ-features that play a central role in language (see articles in Harbour *et al.* 2008) and are involved in agreement, an important phenomenon in language that is likely unique to humans. I argue here that all of the semantics of person, number, and gender are shared with vertebrates, that many are with insects, and that some are with plants.[1]

The findings presented here argue against the idea that there is something uniquely human and communicative to the categories grammar regularly makes use of. Mithun claims that:

> It is now generally recognized that grammatical categories develop in languages through use. Distinctions made most often by speakers as they speak tend to become routinized over time in grammatical markers. Many grammatical categories recur in language after language, no doubt because they reflect common human interests. (Mithun 2015: 131)

The data I present here suggest that ϕ-features at least did not develop in grammar through language use but are part of the innate cognitive structures we share with other living things. It seems that ϕ-features reflect common living interests and are part of the faculty of language in its broad sense (FLB), which includes "a wide variety of cognitive and perceptual mechanisms shared with other species […] in more or less the same form as they exist in humans, with

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[1] A reviewer raises the issue "whether there is something like a language-specific semantics on the one hand and a language-independent semantics on the other hand". I assume that the semantics of ϕ-features are language independent, though I cannot speak past that to semantic issues more generally.

differences of quantity rather than kind" (Hauser *et al.* 2002: 1573). Person, number, and gender do not seem to be part of the faculty of language in its narrow sense (FLN), the discretely human part of language, and do not reflect interests specific to humans. Most people never think or care about person, number, or gender in the grammatical sense.

There is a split among some linguists between more formal approaches that see language as mostly representational and innate and more functional approaches that see it as mostly communicative and learned. This paper partially supports the more formal view by arguing that grammatical categories are shared with animals that do not use them for communication at all and only use them for cognition (humans use them for both). Also, most of the ϕ -features have clear neural and genetic bases that suggest they are innate rather than learned.

A note about animal cognition. The main line of research here is in how animals process information related to what biologists call the four Fs—feeding, fighting, fleeing, and reproduction. It is not in how animals think about the information they process; i.e., none of the claims here involve animal metacognition (for which, see Kornell 2014). The issue in this paper is *Do animals think* ***using*** *person, number, gender?* It is not *Do animals think* ***about*** *person, number, gender?*

Two notes about what I do *not* claim. First, the semantics of grammatical categories like number are quite specific and meager: The grammatical features singular, dual, and plural do not have anywhere near the depth of meaning that humans enjoy in lexical items like *single, twin, fifteen,* π, etc. Claiming that guppies process singular, dual, and plural like humans do does not mean that they possess all of our numerical skills, nor that they use their mathematical skills as we do ours. The claim is much more restricted: *singular, dual, and plural are used by animals in their natural settings*. Second, I do not claim that what is shared with other animals is necessarily derived from a shared common ancestor; other animals have eyes but many are the result of convergent evolution. The argument for inheritance has to be made on a case-by-case basis and I will indicate where this has been done below. The claim is just that *person, number, and gender semantics are not uniquely human.*

I begin with the features behind the category *person* as it unfolds in grammar and in animal cognition (section 2), then turn to *number* (section 3) and *gender* (section 4), before briefly concluding with some broader concerns (section 5).

2. Person

All human languages mark grammatical person, usually in pronouns like *I, you, he, she, it*, and it is common to see person features copied onto a verb or other predicate, as we see in a language like German, where verbs agree in person and number with their subjects:

(3) *German*

Ich geh–e	Du geh–st	Sie geh–t
1SG go–1SG 2SG	*go–2SG*	*3SG.F go–3SG*
'I go'	'You go'	'She goes'

Person lies behind the notions speaker (1P), hearer (2P), and other (3P), but there is reason to see it as based more deeply on the concept *self*. The idea goes back over a century:

> Le point de départ est le moi psychologiquement; du moi, on passe au non-moi. Mais le fait du discours introduit un troisième élément et divise le non-moi; on ne parle pas sans interlocuteur; cet interlocuteur se détache du groupe du non-moi et prend une importance particulière.
>
> Celui qui parle divise ainsi les êtres en trois groupes: 1° soi qui parle, 2° celui à qui il parle, 3° ce dont il parle. (Grasserie 1888: 3)

Person is linked specifically to *self* as early as Boas: "Logically, our three persons of the pronoun are based on the two concepts of self and not-self, the second of which is subdivided, according to the needs of speech, into the two concepts of person addressed and person spoken of" (Boas 1911: 39). The grammar of the Papuan language Urama codes this distinction of self and not-self overtly:

> There are only two overt person markers in Urama. One of them marks the first person of all numbers. The other one marks the second and third person of all numbers and as such is a 'non-speaker' form. (Brown *et al.* 2016: 27)

Thus a verb agreeing with 1P has the prefix *n–* (glossed 1 for 'first person'), while a verb agreeing with 2P or 3P has the prefix *v-* (glossed N1 for 'non-first-person'):

(4) *Urama*

a. Nimo nahua=i n–abodo ka=umo.
1PL song=DEF 1–sing PRES=PL
'We are singing the song.'

b. Rio hatitoi v–odau du=mo?
2PL whither N1–goTENSE=PL
'Where are you all going?'

c. Ni raisi itai a–v–o'ou du=mo doutu?
3PL rice cook Q–N1–DFUT TENSE=PL tomorrow
'Will they all cook rice tomorrow?'

(Brown *et al.* 2016: 28–29)

The importance of the notion *self* for 1P and 2P generally is treated in Bobaljik (2008: 224ff.) and Wechsler (2010), who argues convincingly that "first- and second-person pronouns are not grammatically specified for reference to speaker and hearer" (p. 362), based on evidence from typology, acquisition, and autism (to which the reader is referred). Mizuno *et al.* (2011) likewise argue that pronoun-reversal in autism (generally *I* for *you*) is the result of a failure to shift the "deictic centre from another person to oneself" (p. 2433). As Wechsler points out, the autistic data make no sense if 1P and 2P mean 'speaker' and 'hearer', concepts which autistic individuals should have no difficulty with.

I follow Wechsler's claim that "ALL PRONOMINAL REFERENCE TO SPEECH-ACT PARTICIPANTS takes place via SELF-ASCRIPTION" (Wechsler 2010: 349, his caps), also known as reference *de se* or *self-reference*. When speakers say 'I' they refer to themselves, and when addressees hear 'you' they refer to themselves. For him,

> SELF-ASCRIPTION EXHAUSTS THE PERSON SEMANTICS OF THESE FORMS. […] These pronouns indicate self-ascription, but there is no additional specification that they must 'refer to' or 'be anchored to' the addressee and speaker. […] For every speaker, *I* translates as a self-notion, and for every addressee, *you* translates as a self-notion. (Wechsler 2010: 348, his caps)

3P translates as everything else, occasionally to other actual people but much more commonly to animals, plants, rocks, dirt, clouds, warmth, situations, events, hypotheticals. The referents of 1P and 2P form a remarkably small set of usually human *selves* compared to the referents of 3P which cover the rest of the world and everything in it: all nouns are 3P in every language.

2.1. First Person

If 1P actually denoted speakers, a sentence like *I am not speaking* would be logically false or interpretable only metaphorically, which it clearly is not. 1P need not coincide with someone who is speaking and *I am speaking* is not a tautology in any language. Nor does 2P need to coincide with an addressee: *You are speaking*, where the speaker is 2P, is perfectly grammatical and need not be interpreted metaphorically to be true. Nor are *She is speaking* or *She is listening* logically false or semantically anomalous in any language. Speakers need not be 1P and 1P need not include speakers. Everyone uses 1P to refer to themselves when they speak, but the intended referent is *self*, not *speaker*. People with associative identity disorder have multiple *selves*: the referent of 1P shifts from one personality to another, not from one speaker to another (schizophrenia might be similar, see Gallagher 2000: 15ff.).

That said, what 1P encodes *grammatically* is incredibly spare and utterly devoid of content in the languages of the world, as discussed in the philosophical literature:

> 'I' seems to lack descriptive content entirely. Importantly, there is no need for the speaker to 'know who' he is, i.e. who is uttering 'I', in order to successfully refer by its use. The speaker may have entirely false beliefs about himself or no identifying beliefs at all. None the less, when the speaker utters a sentence containing 'I', he refers to himself. By the use of 'I' one refers to oneself without any further characterization.
> (Röska-Hardy 1998: 3)

Gallagher distinguishes a rich *narrative self* from a lean *minimal self*:

> Phenomenologically, that is, in terms of how one experiences it, a consciousness of oneself [is] as an immediate subject of experience, unextended in time. The minimal self almost certainly depends on brain processes and an ecologically embedded body, but one does not have to know or be aware of this to have an experience that still counts as a self-experience.
> (Gallagher 2000: 15)

1P is essentially what Descartes (1641) argued was the one thing he could not doubt:

> Sed quid igitur sum? Res cogitans. Quid est hoc? Nempe dubitans, intelligens, affirmans, negans, volens, nolens, imaginans quoque, & sentiens.
> [But what then am I? A thinking thing. What is that? Surely doubting, understanding, affirming, denying, wanting, refusing, imagining too, and feeling.] (*Meditations* 2.8)

In some languages, persons combine to form 'inclusive' or 'exclusive' duals and plurals. Wikchamni Yokuts, for instance, contrasts *inclusive our* (1P and 2P) and *exclusive our* (1P and 3P) in both duals and plurals. The inclusive forms are built on a 2P root (*m–*), while the exclusive forms are built on a 1P root (*n–*):

(5) *Wikchamni*

Dual	Plural		
m–akʔan	m–aːy'in	'our (1P and 2P)'	*(includes you)*
n–imkin	n–imik'	'our (1P and 3P)'	*(excludes you)*

(Gamble 1978: 101)

Bobaljik (2008) notes that no language distinguishes 1P duals or plurals in terms of [1P +1P] vs. [1P +3P], that is, no language has a special morpheme for 'true 1P' or 'true 2P'.

Most animals use the *self* as a reference point to function in their natural environment. Spada *et al.* (1995: 194) define this kind of biological *self* as the "ability of a living organism to be an active agent in its physical and social environment by means of a continuous monitoring of its position in relation to any environmental situation, i.e., danger, hunting, attack, etc." *Self* also includes all interoception—hunger, thirst, cold, fatigue, arousal. Spada *et al.*'s notion of *self* for animals is, like Descartes', a thing that sees, hears, feels, and thinks.

Bekoff & Sherman (2004) argue that *self* is too broad a term when discussing the animal world and distinguish three levels of *self* for animal minds. Two of these, *self-referencing* and *self-awareness,* are said to be shared with other beings, while the third, *self-consciousness,* is thought to be unique to humans. They define *self-referencing* as a simple dichotomy of *me* vs. *others* that "can be reflexive and noncognitive, even occurring in the immune system and in creatures without brains, such as tunicates [commonly known as sea-squirts, invertebrate marine filter-feeders with no sense organs—CG] and plants" (p. 177). If a plant or animal's immune system cannot tell itself from other things, it will attack the plant or animal it is meant to defend: in this very basic sense *self* is a general notion that requires no cognition at all. I take Bekoff & Sherman's *self-referencing* to be a biological pre-cursor to the categories 1P and 2P, one that is shared among eukaryotes, bacteria, and archaea, all of which have immune systems; *self-referencing* probably traces back to the last universal common ancestor (LUCA).

Bekoff & Sherman's notion of *self-awareness* includes *self-referencing* but also distinguishes things like *my body* vs. *others' bodies*. I would argue that *self-awareness* in this sense is 1P in its grammatical sense and is widely shared among animals (including humans), but not by single-cell organisms:

> A sense of 'body-ness' is necessary for most animals to function in their social and ecological milieus, i.e. to find mates, to evade predators, or to avoid bumping into each other. A brain is required for this level of self-cognizance, although the actual discrimination can be conscious or unconscious.
>
> (Bekoff & Sherman 2004: 177)

Bekoff & Sherman's *self-awareness* is clearly meant in a 1P sense: An animal is immediately aware of itself. De Waal (2016: 241) points out that when two monkeys play, they bite *each other* (2P) rather than *themselves* (1P); they can only do so if they distinguish 1P from 2P. The details of all this are less important than what these conceptions of animal self share: They are meager and include little or nothing of substance, for example, no knowledge of *self* in a biographical sense. They seem to be the exact homologues of 1P *self* in grammar.

Some such notion of *self* is required not just for locomotion in animals, but for the spatial mapping that guides it. A core element of such mapping is *egocentric* mapping, the use of neural spatial reference frames that include the *self*:

> It is well-established that neurons in many brain regions, especially parieto-frontal cortex, represent the spatial location of objects in egocentric spatial reference frames, centered on various body parts such as the eye (retina), the head, or the hand. […] [Egocentric frames are involved] whenever the observer invokes the position or orientation of the present, remembered or imagined (e.g., mentally rotated or translated) self, as opposed to an external landmark, to represent the location of external landmarks.
>
> (Filimon 2015: 1–2)

Navigation in all animals is thought to involve egocentric representations. Anderson & Oates (2003) conjecture that prelinguistic animals can have *only* these and Filimon (2015) argues that all spatial mapping is egocentric for humans as well. Most of the field, however, assumes a healthy mix of egocentric and allocentric mapping: "[B]oth allocentric or 'survey' strategies, based on the manipulation of map-like representations, and egocentric or 'route' strategies, based on path integration or on sequences of stimulus-response associations, contribute to human navigation" (Galati *et al.* 2010: 113). Visual navigation in water mazes by rats (Harvey *et al.* 2008) shows both egocentric (e.g., keeping a visual cue in the center of the retina) and allocentric navigation (discussed below under 3P). Recent work with moving ferrets shows this for auditory cortex as well (Town *et al.* 2017). Even insect navigation relies on where the *self* has been (Collett *et al.* 2013).

Bekoff & Sherman's third level, *self-consciousness,* involves thinking about oneself and one's relation to others:

> Being self-conscious implies that an individual is self-aware, and that it can use self-referent phenotype matching. We hypothesize that self-consciousness evolves when individuals benefit from analyzing and revising their own behavior in light of how specific members of their social group, including actual or potential mates, responded to their behavior in the past.
>
> (Bekoff & Sherman 2004: 177)

They do not speculate on which animals have self-consciousness in this sense, but this need not deter us here. Grammatical 1P is based on *self-awareness*, not the much richer notion *self-consciousness*.[2]

A related trichotomy in neuro-science is the distinction between mental states arising from the *protoself*, the *core self*, and the *autobiographic self*, associated with Damasio (1998, 1999, 2010). Mental states of the last kind "are generated when individuals retrieve memories for historical aspects of their lives, and thus are dominated by biographical information, including simple facts of one's identity (e.g., date and place of birth), personality traits (e.g., honesty), as well as specific life events and episodes (e.g., one's high school graduation)" (Araujo *et al.* 2015: 2). These may well be unique to humans and an autobiographical sense does not seem warranted in the cognition of most animals; nor is it warranted in grammatical 1P. What grammar codes is the mental states of the *core self*: "Such states allow individuals to form an account of their ongoing body states, and may relate to interoceptive body changes (e.g., hunger, thirst, or fatigue), and to a class of exteroceptive changes caused by the interaction of the body with the outside world (e.g., pressure exerted on one's arm)" (Araujo *et al.* 2015: 2).

Damasio takes the *protoself* to be a biological precursor to the core self.

> The protoself is the stepping-stone required for the construction of the core self. *It is an integrated collection of separate neural patterns that map, moment by moment, the most stable aspects of the organism's physical structure*. The protoself maps are distinctive in that they generate not merely body images but also *felt* body images. These primordial feelings of the body are spontaneously present in the normal awake brain. (Damasio 2010: 201, his italics)

The neurological *core self*, biological *self-awareness*, and philosophical *I* seem to be describing the same thing from slightly different angles. My claim here is that the notion 1P in grammar describes the same biological mechanism.

Summarizing, 1P behavior is widespread among animals and involves a stripped-down notion of *self* essentially identical to the one that grammatical 1P encodes.

2.2. *Second Person*

Still following Wechsler (2010), the referent of 2P is again the *self*; the difference between 1P and 2P is that 2P references the *self* for an addressee, while 1P references the *self* for a speaker. Since we cannot profitably use terms like *speaker* and *addressee* when discussing animal behavior (they don't speak), separating 1P from 2P in cognition is less obvious than it might seem. The general picture, however, is that 1P indicates a *self* that is *me*, while 2P indicates a distinct *self* that I am engaged with. This 2P *self* is generally human for us, though it can be extended to animals that function as humans in some way (e.g., pets and farm animals). As pointed out by a reviewer, I can and do address my dog as *you*, though I doubt he responds to it with self-ascription; when I address my (adult) daughter as *you*,

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[2] Whether animals recognize themselves in mirrors is sometimes taken to be relevant to the notion *self* as well; the issue strikes me as tendentious and I will not address it here.

self-ascription goes through as planned. So the relative propriety of addressing my daughter > my dog > my car as *you* is well-modeled as a function of how well each of them can self-ascribe the notion *self*: my daughter does so fully, my dog less so, my car not at all.

With this caveat, I assume that grammatical 2P involves close interaction of the *self* with a conspecific, where each is usually aware of the actions of the other and the actions are coordinated in some way. Although most humans invest much more than this in interpersonal interactions, grammatical 2P encodes just this and no more.

This is how 2P is used in most of the cognitive science literature, where it is not related to speaker/addressee but to perspective-taking, modes of social interaction, and the like. I follow de Bruin *et al.*, who

> propose that what distinguishes 2p from 3p modes of social cognition is their reciprocal nature. That is, 2p modes of social cognition feature agents who coordinate their actions with one another. (de Bruin *et al.* 2012: 8)

Evidence for 2P cognition in animals comes from *dyadic interaction*, what Hurford (2007: 198) calls "doing-things-to-each-other: aggression, sex, submission, feeding another, grooming, caregiving, and play". Dyadic interactions involving shared gaze and attention implicate the basic notions of 1P and 2P and "are commonplace in many species of animal; shared attention during social play with objects has been observed in some canid, psittacine, and corvid species" (Tanner & Byrne 2010: 592). "Jackdaws […] follow a conspecific's gaze toward the object of their attention concealing food, but only when the conspecific is their partner, not when unfamiliar to them" (Clayton & Emery 2015: 1337).

Mating displays in certain fish require coordinated 2P actions as well. Consider the following dyadic interactions of the mangrove killifish:

Tandem swim:	Fish pair up and move through the water column. Includes side-by-side swimming or one fish following closely behind the other.
Vertical rub:	Fish positions body vertically and uses entire body to make contact with opposing fish, which is suspended horizontally in water column.
Head rub:	Fish uses head to make contact with opposing fish; often, point of contact is underneath the vent of the opposing fish.

(Luke & Bechler 2010: 9)

Interactions like these require that a fish be aware of the actions of its partner and that the actions of both fish be closely coordinated. There is no indication that killifish communicate about any of this, suggesting that 1P and 2P are not fundamentally about communication, but about coordinating interactions with a conspecific.

When insect colonies relocate, individuals must be guided to the new area. Some species do this with a 2P method called *tandem running* (Franks & Richardson 2006):

> In brief, it is a behaviour involving two individuals walking one behind the other in tandem, maintaining physical contact. The individual in front has prior knowledge of the destination, be it the new nest or food source or nest of slave species, and is known as tandem leader. The follower or second individual in the pair is the recruit and she is led to the destination. The recruited member in turn can behave as an informed individual and recruit other colony members or be only a follower and stay at the destination. Throughout the journey, the follower maintains contact by tapping her antennae on the gaster of the tandem leader thereby forming a tandem running pair. In some species of ants, pheromones are said to play an important role in initiating and maintaining cohesion between the tandem pair. Studies in *T. albipennis* suggest that followers learn the destination and make independent explorations to navigate back to the old nest and become recruiters in turn. (Kaur *et al.* 2017: 2)

In some species, carefully coordinated *tandem calling* is used to initiate tandem running:

> When a successful scouting forager returns to the colony it first regurgitates food to several nest mates. Then it turns around and raises its gaster upward into a slanting position. Simultaneously the sting is exposed and a droplet of a light liquid extruded. Nest mates are attracted by this calling behavior. When the first ant arrives at the calling ant, it touches the caller on the hind legs or gaster with its antennae and tandem running starts.
> (Möglich *et al.* 1974: 1046)

All of this requires careful coordinated actions between reciprocating conspecifics, each aware of the actions of the other. Most ant species actually carry conspecifics to a location, which also requires a great deal of interpersonal interaction, especially as the ant that is carried has its head upside down and pointing backwards (Pratt *et al.* 2002: 126).

> The collective achievements of these colonies draw attention, not to a gap between the intelligence of workers and the colony as a whole, but rather to the difference in scale. Even when no insect possesses information on more than a small part of the colony's task, an adaptive global solution can emerge from their local interactions, guided by appropriate individual behavioral rules. Because these local interactions may themselves involve sophisticated information processing, a thorough understanding of colony cognition requires a full appreciation of the cognitive skills of individual insects.
> (Pratt *et al.* 2002: 127)

I submit that the cognitive skills of individual insects include a notion of 1P and 2P that bind with DUAL and PLURAL.

There is evidence for 2P in animal *communication* as well, though that is not the focus of this paper:[3]

> Dyadic communication involves only two creatures: a sender and a receiver of a message. Such communication is not about anything external to the sender and the receiver. It is just a matter of one animal or person doing something to another, like greeting it, or threatening it, or submitting to it. This kind of communication is widespread in the animal kingdom.
> (Hurford 2007: 205)

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[3] See Schlenker *et al.* (2016) for a linguistic approach to communication in monkeys.

Sauerland (2016) argues that the semantics of a certain Colobus monkey call "explicitly mentions the addressee—i.e. *you*" and that "a Colobus monkey needs to attribute a mental state to the recipient" of its call (p. 151).

How far back in time 2P reaches is difficult to say, but it may be universal among social animals.

2.3. *Third Person*

3P reference in languages includes everything in the world other than the tiny number of *selves* referred to by 1P and 2P, a large map of everything with an X marking *you are here* and innumerable y's and z's marking everything else. We track our position among the y's and z's and navigate our way through them, through a maze of 3P places and things. Relatively few of the third person referents are *persons*; many are non-human (*dogs, cats, birds)* and most are inanimate *trees, rocks, roads, parks, attitudes, problems, events, situations*.

The psychology literature tends to use the term 3P for actual third *persons*, for example: "We experience our world from an egocentric (i.e. first-person) perspective and only later develop an ability to understand experiences from the perspective of others (i.e. third-person)" (Chisholm *et al.* 2014: 2). But this is not how the grammar of any language works: Grammar sees everything as 3P that is not 1P OR 2P.

The question at hand is whether animal cognition makes use of such a notion, whether animals distinguish things in the world (3P) from themselves (1P) and the selves they are currently interacting with (2P). Following Ungerleider & Mishkin (1982) and others, there are two visual processing systems in the brain, a ventral one that focuses roughly on *what* an object is and a dorsal one that focuses roughly on *where* it is. Goodale & Milner suggest that the ventral 'what' stream is more about the object itself (more 3P in grammatical terms), while the dorsal 'where' stream is about the relation between the object and the self (more 1P) and "would need to be largely 'viewer-centred', with the egocentric coordinates of the surface of the object or its contours being computed each time the action occurs" (Goodale & Milner 1992: 23). This makes sense if hapsis and navigation rely on spatial relations *vis-à-vis* the self, relations which object identification does not rely on. More recently, Manns & Eichenbaum (2009: 616) argue, based on neural data from mice, that the hippocampus may be where the map is located in mammals: "[T]he results suggest that objects were represented as points of interest on the hippocampal cognitive map and that this map was useful in remembering encounters with particular objects in specific locations".

Hurford argues that the dorsal/ventral stream distinction in perception is basic to the predicate-argument structure of logic and language:

> [T]he formula PREDICATE(x) is a simplifying schematic representation of the integration by the brain of two broadly separable processes. One process is the rapid delivery by the senses (visual and/or auditory) of information about the egocentric spatial location of a referent object relative to the body, represented in parietal cortex. The eyes, often the head and body, and sometimes also the hands, are oriented to the referent object, which becomes the instantiation of a mental variable. The other process is the somewhat slower

> analysis of the delivered referent object by the perceptual (visual or auditory) recognition subsystems in terms of its properties. (Hurford 2003: 273)

We look at the *where* first, and the *what* second in what follows, though it is important to note that they function together in parallel in neurologically intact animals.

2.3.1. Where

Clear evidence that animals have 3P representations of some sort involves spatial orientation and navigation in animals, which is generally taken to be partly egocentric (1P) and partly allocentric (3P)—to my knowledge, there is no biological literature on how we map our position to that of a conspecific we are interacting with (2P). The *locus classicus* for the idea that animals build cognitive maps is Tolman (1948), reporting on a number of experiments with rats in mazes. Arguing against behaviorist explanations, he says of 'field theorists' like himself that:

> We believe that in the course of learning something like a field map of the environment gets established in the rat's brain. […] This position […] contains two assumptions: First, that learning consists not in stimulus-response connections but in the building up in the nervous system of sets which function like cognitive maps, and second, that such cognitive maps may be usefully characterized as varying from a narrow strip variety to a broader comprehensive variety. (Tolman 1948 :192–193)

The general consensus for the past half century is that animals map the world they live in, not just in egocentric but also in allocentric terms, all of which are coded 3P in grammar. In a review of navigation in humans, Ekstrom *et al.* argue against the idea that allocentric representations are actually *maplike*, but acknowledge that "the idea that most species, including humans, posses multiple mechanisms for navigating, including one dependent on information about the position of the self relative to the environment (egocentric) and another regarding the position of other objects position relative to each other in the environment (allocentric), is generally well accepted" (Ekstrom *et al.* 2014: 1).

I follow Tolman, Gallistel, and most of the field in thinking that maps provide an excellent model for animal navigation, but it is true that the exact details of all this remain unclear. For the purposes of this paper, it does not matter if the allocentric 3P representations are literally map-like or not; all that matters is that they are 3P.

Damasio distinguishes three types of mapping, two of them internal to the organism, the third external:

> A normal mind includes images of all three varieties. […] (I) Images of an organism's internal state constitute primordial feelings. (II) Images of other aspects of the organism combined with those of the internal state constitute specific body feelings. Feelings of emotions are variations on complex body feelings caused by and referred to a specific object. (III) Images of the external world are normally accompanied by images of varieties I and II.
> (Damasio 2010: 80)

Most of the biological literature on mapping, though, is of the external kind. A classic discussion of cognitive maps in insects is found in Gallistel (1989):

> When a foraging ant leaves the nest, it winds this way and that in a tortuous search for fodder, but when it finds something, it turns and runs more or less directly back toward its nest a 1-mm hole in the ground as much as 200 m away. It does not retrace its outward path. If the ant is displaced at the start of its homeward run, it nonetheless runs straight in the predisplacement direction of the nest for a distance approximately equal to the predisplacement distance to the nest, then breaks into a search pattern. It is hard to resist the inference that the foraging ant possesses a continually updated representation of its spatial position relative to its starting point—a moment-to-moment representation of the direction in which the nest lies and how far away it is.
>
> When one displaces the landmarks that immediately surround either a bee's feeding source or the nest hole of a digger wasp, the position to which the animal flies is systematically displaced. It is hard to resist the inference that the animal represents something about the spatial relationship between the landmarks and its goal and uses this representation to direct its flight toward the goal. (Gallistel 1989: 155–156, references omitted)

More recent work on foraging ants suggests this even more clearly: they can find their way back to their nests walking *backward*, that is, even when egocentric navigation is thwarted, showing that they use allocentric directional frames, including the position of the sun (Schwartz *et al.* 2017). Bumblebees make similar use of map-like representations and can correct for things like wind drift, which does not seem possible if only egocentric representations are used:

> We have investigated wind compensation […] using radar to record the flight trajectories of individual bumble-bees (*Bombus terrestris L.*) foraging over arable farmland. Flights typically covered distances of 200 to 700 metres, but bees maintained direct routes between the forage areas and their nests, even in winds with a strong cross-track component. Some bees over-compensated slightly […] but most stayed on course by heading partly into the wind and moving obliquely over the ground. […] We propose that a simple strategy to keep on track in cross-winds would be for them to adjust their headings until the direction of ground image movement over their retinae (the optical flow) occurred at the angle relative to the sun's azimuth that corresponded to their intended tracks. (Riley et al 1999: 126)

Navigation in birds is generally understood in terms of a map and compass model (see Chernetsov 2015, which this section heavily draws upon). Like the rest of us, birds have to know where they are with respect to where they are going (the map) and they have to travel in a specific direction (the compass) to get there, both of which involve detailed 3P representations of the world and the things in it. Avian *compasses* are based on the sun, the stars, and the magnetic field of the earth. Avian *maps* are less well understood but include geomagnetic maps of the earth and possibly olfactory maps as well, based on the fact that birds cannot navigate if their sense of smell is destroyed experimentally.

Some of this navigation is learned and some is innate, as shown by displacement studies, in which birds are moved to a different location before they migrate (or return home in the case of homing pigeons) to see what effect this has on where they end up. The major finding is that (experienced) adults and (naïve) juveniles show up in different places:

> [A]dult birds can truly navigate in the sense that they can direct their movements specifically towards a goal, and when displaced during migration, they alter their headings accordingly. Juvenile birds on their first migration, in contrast, do not do this. The reason is not that they lack the ability to navigate—young migrants have been shown to be able to navigate at the respective age. […] What they lack is the navigational information about the goal area—first-time migrants travel to a yet unknown winter quarter. Birds can truly navigate only to a familiar goal where they know the 'local coordinates'. (Wiltschko 2017: 457)

This strongly suggests that adult birds manage to construct cognitive maps of their migration routes, which shows a careful monitoring of the 3P world as they mature. Displaced juveniles end up somewhere else because they have not yet built such maps:

> Young first-time migrants thus have to use a different strategy. Some avian species, such as, e.g., geese and cranes, migrate in family groups or flocks […] and young birds could, theoretically at least, be guided by their parents or experienced conspecifics. Yet, in most species, the young birds migrate independently from experienced birds, sometimes even leaving before the older birds leave. For their first migration, these birds have to rely on innate information to reach their wintering area. (Wiltschko 2017: 457)

Much is known about innate migration programs, but for our purposes it suffices that they indicate intricate 3P world knowledge, including the direction and length of the migration route.

Reptiles and teleosts (bony fish) also behave as if following maps; see Rodríguez *et al.* (2002) for a number of experiments which show "that turtles and goldfish, like mammals and birds, are able to use place strategies based on map-like or relational memory representations of the allocentric space" (p. 501ff.). The same is true of lizards, once thought to be insensitive to place memory (LaDage *et al.* 2012).

The point of the present section is not that grammar encodes the azimuth of the sun or the earth's magnetic field; these are 3P issues relevant to other animals, not to us. The point of this section is that all animals have rich 3P representations of their environment, based on their biological needs. Spatial relations among 3P objects are not the only 3P representations, of course, but they are well-studied and are common if not universal among animals.

For vertebrates it looks like such spatial mapping is inherited from our last common ancestor. Rodríguez *et al.* (2002) point out "that mammals, birds, reptiles, and teleost fish share a number of similar basic spatial cognition mechanisms, in particular, that all of these vertebrate groups have place memory capabilities, based on maplike or relational memory representations of the allocentric space" (p. 499); "the close functional similarity among the hippocampus of mammals and birds, the medial cortex of reptiles, and the lateral pallium of teleost fish suggest that early in the evolution of vertebrates, the medial pallium of an ancestral fish group that lived some 400 million years ago and gave rise to these extant vertebrate groups became specialized for encoding and processing complex spatial information, possibly as a navigational device that has been conserved through the evolution of each independent vertebrate lineage" (p. 502).

2.3.2. What

The maps our dorsal stream helps construct are populated by objects that are grammatically coded 3P. Psychologists and biologists tend to concentrate on actual *objects*, but of course language has many 3P referents that are not objects in any real sense: properties, emotions, relations, situations, events. And from a grammatical perspective, *3P is just 3P*, without any differentiation as to type (aside from gender, *q.v.* below). The most critical external 3P referents include predators, prey, and conspecifics, and there's reason to think that most or all animals process the world in terms of such categories.

The notion *conspecific* seems to be innate for reptiles (Suboski 1992: 75) and fish (Hawkins *et al.* 2004: 1250), but is a mix of innate and learned for birds and mammals. A well-known case is imprinting in young birds, who *can* imprint on a red box (learned) but have an innate predisposition to imprint on something that looks like their mother (innate, Bolhuis & Honey 1998). Birds raised by other species of birds generally prefer to mate with their *adopted* species, showing that avian conspecificity is more learned than innate (Irwin & Price 1999). In a study of cuckoos (brood parasites that lay their eggs in nests of other species that end up raising them), Soler & Soler 1999 introduced some nestlings into nests in pairs and others alone:

> When two cuckoos were introduced into the same nest, they behaved like cuckoos on leaving the nest. […] That is, they learnt to recognize their own species. When only one cuckoo was introduced per nest, at fledging they did not join a group, even when they met other cuckoo fledglings. […] Thus, these fledgling cuckoos did not recognize conspecifics when they were reared without any other cuckoo nestling in a nest where we experimentally prevented contact with adult cuckoos. (Soler & Soler 1999: 100)

An animal that recognizes conspecifics, innately or not, has 3P representations that divide the world up in a very specific way; conspecifics are of course the ideal 2P referents as well.

Predators form a special class of 3P representations that are innate in many species, as we know from our fear of snakes. Fear like this is intentional in the sense of being *about something* in the environment like a predator or dangerous conspecific, and it can tell us a great deal about the 3P representations an animal has. Silva *et al.* see

> 'fear' as a central state, which is induced when the subject perceives danger and that mediates bodily and behavioral responses to such danger. These responses include defense mechanisms that are necessary for the survival of the individual and can be observed in virtually all animal species. Fear responses are triggered by a variety of stimuli, including predators, aggressive members of the same species, pain, and dangerous features of the

> environment such as heights. Importantly, these types of stimuli strongly and systematically induce defensive behaviors and do not depend on the experience of direct harm associated with the threat nor on a learning process assigning a valence of danger to the threat. This type of fear is what has been referred to as 'innate fear'. (Silva *et al.* 2016: 544, references omitted)

If we want to know what it is like to be a bat, we should probably think of *fear*. Like much of an animal's 3P world, fear is driven not only by sight and sound but by smell: "Prey species belonging to many taxa, including birds and mammals, amphibians, reptiles and crustaceans, show an innate ability to recognise predator odour cues" (Hawkins *et al.* 2004: 1251, references omitted).

Pheromones regulate massive amounts of an animal's world, "including modulation of puberty and estrous; control of reproduction, aggression, suckling, and parental behaviors; individual recognition; and distinguishing of own species from predators, competitors, and prey" (Liberles 2014: 151). All of this implicates 3P in grammar, just as much as objects in the visual field do. Similarly for "other odor-driven behaviors, including responses to sickness cues, alarm pheromones, social dominance cues, nest pheromones, and odors that underlie the social transmission of food preference" (p. 167).

A good deal of 3P perception seems to be innate: "A considerable amount of evidence has been accumulated in the last century which suggests that all vertebrates, from primitive fishes to primates, are able to recognize important classes of stimuli, including visual objects, sounds and pheromones, with no previous experience of those types of stimuli" (Sewards & Sewards 2002: 861). Innateness is less of an issue for us than for frogs and toads, but it is there:

> In primate species, visual object recognition in early infancy is innate and entirely mediated by subcortical structures, and cortical visual areas are essentially non-functional. During the transition period, both the subcortical and cortical systems function, and thereafter only the cortical (learned) visual system operates overtly. This ontogenetic sequence mirrors the phylogenetic progression from the all-innate visual system of anurans to the dual system of birds and rodents, and ending in the all-cortical system of primates. (Sewards & Sewards 2002: 884)

Leaving vertebrates, insects also have innate object recognition. Innate prey recognition, for instance, has been shown experimentally for praying mantises (Prete *et al.* 2011) and jumping spiders (Dolev & Nelson 2014). The schemata involved are probably more a function of the prey than the predator:

> [S]imilar prey-recognition schema are used by animals with very different brains, for instance, amphibians, the amphibious fish *Periophthalmus koehlreuteri*, cuttlefish, and mantises. For all of these animals, objects that elicit appetitive behaviors are defined by their inclusion within a perceptual envelop that includes a variety of images all of which share some subset of certain key stimulus characteristics. (Prete *et al.* 2011: 891, references omitted)

3P representations are rich, varied, and common in animals, from insects to primates. Some of these are innate, even for primates, and some are learned, but the world apart from the *self* is well-mapped and well-populated.

2.4. Multiple Persons

Do animals distinguish 2P vs. 3P interactions? Evidence that they do comes from *triadic* interactions involving two animals (usually of the same species) engaged with each other and a third object (usually inanimate). It is clear, for instance, that "gorillas engage with conspecifics in collaborative social activities involving objects; when they do, they perform many types of behavior that in humans are criteria for triadic interaction and experience-sharing" (Tanner & Byrne 2010: 592). Special cases of triadic interaction that have been studied in humans and other animals are gaze following (*I look at what I think you're looking at*) and joint visual attention (*we both look at the same thing, and know it*), which simultaneously demonstrate 1P and 2P interaction with a 3P object. These seem to be much less common in the animal world than are simplex 1P, 2P, 3P. In a review, Itakura (2004) notes that there is positive evidence for gaze following and joint attention in primates (macaques, capuchin monkeys, gibbons, chimpanzees, orangutans, and gorillas), domesticated animals (dogs, horses), and some birds (jays).

Interestingly, no language grammatically marks {1P, 2P, 3P} in a way that is distinct from {1P, 2P} or {1P, 3P}. A few languages have morphemes that mark, for example, '1P acting upon 2P' or the like, as we find in the Penutian language Nez Perce. In (6) both subject (*boy*) and object (*fish*) are 3P and the portmanteau prefix *pée–* marks this directly (3/3); Crook glosses it as "third person acting on third person":

(6) *Nez Perce*

háacwàl–nim	cùy'éem–ne	pée–k'ùsmì–se
boy–ERGATIVE	*fish–OBJECT*	*3/3–fry–INCOMPLETIVE*

'The boy is frying the fish.'

(Crook 1999: 51)

Nez Perce has a number of suffixes that do the same thing; note that all of them pair exactly two arguments, and thus exactly two persons:

(7) *Nez Perce*

–k	LS/3S, LS/3P, 3S/LS, 3P/LS
–m	2S/LS, 2S/LP, 2S/3P, 3S/2S, 3P/2S, 2S/3S
–nm	3S/LP, LP/3S, LP/3P, 3P/LP
–pem	3S/2P, 2P/LS, 2P/3S, 2P/LP, 2P/3P, 3P/2P
–mek	LS/2S, LP/2S
–pem mek	LS/2P, LP/2P

(Aoki 1970: 130, notation changed slightly)

The Aymaran language Jaqaru has a similar system (Hardman 2000: 57). What seems to be lacking in the grammars of the world are portmanteaux for three persons. A possible reason for this is that the triadic cognition is too phylogenetically recent to have been coded into grammar. (Another is that ditransitives and causatives are just too rare to get their own portmanteaux).

Evidence that animals actively differentiate 1P, 2P, and 3P in the same activity comes from the study of animal play. Burghardt (2010: 340) distinguishes three types of play: "Play in animals means solitary (or parallel) locomotor-rotational play (jumping, leaping, twisting, swinging, running), object play (carrying, dropping, manipulating, biting, mouthing), and social play (chasing, wrestling)". Grammatically speaking, solitary play is 1SG; object play combines 1P and 3P; social play is 1P and 2P—it involves conspecifics, and is often both dyadic and reciprocal. Play has been demonstrated in many monkeys, kangaroos, birds, lizards, and fish and is particularly well-studied in dogs, both feral and domesticated (see Hamon-Hill & Gadbois 2013 for a brief review with respect to 2P). Burghardt stresses that play itself is probably not derived from a common ancestor (p. 347), though this does not affect whether 1P, 2P, 3P are.[4]

Summarizing, it seems that 1P and 3P are evolutionarily quite old and shared not only with vertebrates but with animals generally. A precursor to 1P proper may be found generally in beings with immune systems, as these require the *self-referencing* of Bekoff & Sherman (2004). This may be the case for 2P as well, as seems likely when we consider its connection with conspecificity, which is a broadly shared concept among animals. If it is limited to *social* animals, 2P is much more recent in our lineage and has most likely evolved separately among social insects, birds, and mammals. Placed on a tree of life, the pre-cursor to 1P (*self-referencing*) might go back to the LCA of bacteria, archaea, and eukaryota, all of which have immune systems that differentiate *self* from *other*. 1P proper (*self-awareness*) is likely restricted to *animalia*:

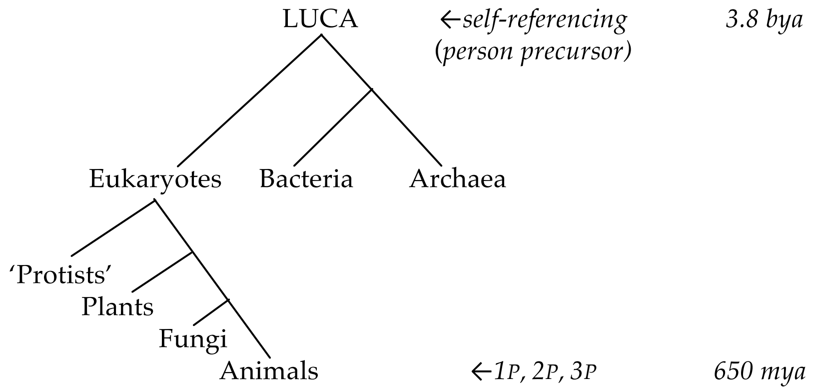

Figure 1: Possible age of person *('Protist' is shown as a group for simplicity).*

3. Number

Grammar has two ways of dealing with amounts, a delicate counting metric used only for small countable quantities, traditionally known as number, and a coarse *more/most* metric used for things that are not countable for some reason. Ancient Greek had simple ways of marking both:

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[4] It is not clear how common social play with an object is; a study of dog–dog and dog–human play found that dog–dog play with an object is much less common than dog–human play with an object (Rooney *et al.* 2000: 246).

(8) *Ancient Greek*

	‘citizen’	‘soldier’	‘son of Atreus’
singular	polí:t–e:s	stratió:t–e:s	atreíd–e:s
dual	polí:t–a:	stratió:t–a:	atreíd–a:
plural	polî:t–ai	stratiô:t–ai	atréid–ai
	‘wise’	‘small’	‘terrible’
positive	sop^{h}–ós	mi:kr–ós	dein–ós
comparative	sop^{h}–óteros	mi:kr–óteros	dein–óteros
superlative	sop^{h}–ótatos	mi:kr–ótatos	dein–ótatos

I will try and show in this section that number and comparatives correspond closely to the two ways animals deal with quantity.

Human numeracy is thought to come in two types, both of them inborn:

> Two non-verbal cognitive systems allow for numerical abilities before educational instruction (see Feigenson, Dehaene, & Spelke, 2004 for review). One, the approximate number system (ANS), allows us to mentally represent, compare, and compute over sets of items on the basis of their approximate numerical magnitude (e.g., Dehaene, 1997). The other, the parallel individuation system (PI), draws on attention and working memory resources to differentiate, track, and remember a limited number of individual items simultaneously (~3 or 4). […] Both systems are present from infancy, are shared with a wide variety of non-human animals, arise from distinct cortical regions, and are characterized by distinct brain and behavioral signatures (Feigenson *et al.*, 2004; Hyde, 2011). (Hyde *et al.* 2017: 1)

The semantics behind these two core number systems are shared for human and non-human animals.[5]

What most animals seem to lack is the successor principle (*x is one more than y*), the notion that allows humans to count (Carey 2009; Spelke 2011; Brannon & Park 2015). It is likely significant that *grammar* has no way of marking this notion: I know of no morpheme in any language that means ‘is one more than’. Grammar seems to mark only those concepts that predate our species and the successor principle is not one of them.

3.1. *Comparatives and Superlatives*

All languages have some way of comparing, usually called *comparative* and *superlative*, e.g., English *–er* and *–est*, or the Greek forms cited above. These are not generally treated as *ϕ-features* in syntax and morphology, in part because they do not seem to be involved in agreement: I am unaware of any language in which verbs agree with adjectives in terms of comparative or superlative morphology, though this may just be my ignorance. Still, comparison is basic to the grammatical systems of most languages and its semantics is usually straightforwardly *more* x, *most* x whether countable (*worms, rocks*) or not (*milk, truth*). The exact gramma-

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[5] This is not to suggest that the human mathematical ability is derivative from language, as Chomsky (2007: 7) has suggested. See Amalric & Dehaene (2010) for the refutation.

tical mechanisms behind comparison are much more diverse than one might expect (Bobaljik 2012; Stassen 2013), though this need not concern us here.

There is broad agreement on the existence of relative quantity judgments in animals, roughly *more/most*, attributed to an Approximate Number System (ANS) they seem to share with us. The ANS may operate on small quantities but most of the evidence for it comes for quantities greater than 3 or 4, with no upper limit, and for comparisons of mass, intensity, loudness, etc. It works in accordance with Weber's Law, which is based on ratios; the larger the ratio, the easier it is to discriminate, so that the difference between 4 and 5 is easier to appreciate than the difference between 14 and 15.

Evidence for an ANS is widespread in animals and comes in various forms. Many studies make use of how animals advance or retreat before larger groups of predators or angry conspecifics, which allows for careful manipulation in experimental settings. McComb *et al.* (1994), for instance, looked at how relative group size affects female lions' decision to approach intruders from another pride. Roars of female lions from other prides were recorded singly or in choral groups of three and replayed via amplifiers hidden in bushes. Some lions heard the roar of a single intruder, others heard the roars of three; some lions were alone or in small groups when they heard the intruders, others were in larger groups. Defenders in small groups were less likely to approach larger groups of intruders and when they did approach them, they did so more slowly, with more pauses, and with more looking at one another than when they approached smaller groups. Mathematically, the

> [n]umber of defending adult females and number of intruders could also be replaced with the single variable 'odds', calculated as the ratio of number of defenders to number of intruders, to produce an equivalent model explaining 60.4% of the deviance in probability of approach. Adult female defenders without dependent offspring preferred odds of 2:1 before approaching, while those with cubs were considerably more likely to approach.
> (McComb *et al.* 1994: 383)

Similarly, "free-ranging dogs are able to assess relative group size in intergroup conflicts and to use this information adaptively: dogs of the packs studied were more likely to approach aggressively opposing packs when the ratio of the number of opposing pack members present to the number of focal pack members present was lower, and were more likely to withdraw from a conflict when the ratio of the number of opposing pack members present to that of the focal pack members present was higher" (Bonanni *et al.* 2011: 111).

Animals choose larger amounts of food over smaller amounts, and this too can be used for determining how they quantify things. In a careful quantitative study, two elephants

> successfully selected the larger of two sets of food items, even when both sets were only presented one item at a time and could not be viewed as an entire set, and thus, the elephants needed to represent the summed total for each set. This confirms that elephants can perform relative quantity judgments. (Perdue *et al.* 2012: 959)

Utrata *et al.* (2012: 8) found "that wolves are able to make quantitative judgments even when alternative strategies such as paying attention to non-numerical properties such as the surface area or time and total amount are ruled out". Vonk & Beran (2012: 237) found that "it is easier for bears to choose the larger amount rather than the smaller amount, even with two dimensional abstract stimuli, and even when they are reinforced for choosing the smaller amount'". And as Ward & Smuts (2007: 71) point out, "[n]atural selection should favor optimal decision-making, but animals must first compare in order to optimize".

Fish seem to have an ANS as well: They prefer large groups to small and choose which group to swim with ('shoaling') based on approximate group size (Agrillo & Dadda 2007). In a typical shoaling experiment (e.g., Agrillo *et al.* 2008, using mosquitofish), a fish is put into the center of a sectioned tank; one end of the tank has two fish and the other end has three, separated from the decider fish by transparent walls. The question is which group the fish in the middle swims toward. Experiments differ in the number of stimuli fish the decider sees (1 *vs.* 2, 2 *vs.* 3, etc.), their size, length, amount of area they cover, how fast they swim, and so on. Agrillo *et al.* used shoaling to compare the mathematical abilities of guppies (*Poecilia reticulata*) with those of undergrads:

> When tested in the same numerical tasks, the students and guppies showed almost identical performance patterns. In both species, the ability to discriminate between large numbers (>4) was approximate and strongly dependent on the ratio between the numerosities. In contrast, in both fish and students, discrimination in the small number range was not dependent on ratio and discriminating 3 from 4 was as easy as discriminating 1 from 4.
> (Agrillo *et al.* 2012: 6)

Reptiles are somewhat understudied with respect to number, but Soldati *et al.* (2017) trained red-footed tortoises (*Chelonoidis carbonaria*) to associate visual cues with more/less food and better/worse food and found that they retained the associations for eighteen months: "This suggests that tortoises can remember the relative value of a reward, and not just its presence or absence, for a period spanning seasons and significantly longer than previously found in hoarder species" (p. 3).

Using various experimental designs (Agrillo *et al.* 2014), support for an ANS has been found in salamanders (Krusche *et al.* 2010) and in birds, including robbins (Hunt et al 2008), parrots (Al Aïn *et al.* 2009), and crows (Ditz & Nieder 2016); see Agrillo (2015) for an overview. The Weber effect in these animals is similar to that found in humans (Revkin *et al.* 2008) and other primates (Beran 2004; Cantlon & Brannon 2007), suggesting that the semantics are the same.

As with comparatives in grammar, the ANS is not restricted to number proper but is also used in comparing things like area (Brannon *et al.* 2006) and time (van Marle & Wynn 2006), which animals are unlikely to compute in strictly numerical terms; see Feigenson (2007) for discussion. Krusche *et al.*'s (2010) work with salamanders suggests that *amount of movement* can be responsible for determining quantity differences as well. So the ANS is a way of determining magnitude rather than number *sensu stricto*—again, it is the vertebrate equivalent of *more*/*most*. The evolutionary roots of the ANS are deep and clear:

> Even the most elementary of organisms [...] are confronted with a never-ending search for the best environment with the most food, the fewest predators, the most partners of the opposite sex, and so on. One must optimize in order to survive, and compare in order to optimize. (Dehaene 1997: 24)

Based in part on the ability of cotton-top tamarins to discriminate number in the absence of training, Hauser *et al.* (2003: 1445) conclude that "humans are not the only species that is spontaneously attentive to number, and that at least part of our non-symbolic system derives from an evolutionarily ancient computational mechanism". More specifically,

> the mental number line seems to be logarithmic rather than linear, and not just in primates, but across vertebrates. It suggests that this way of coding numerical information has evolved based on convergent evolution, because it exhibits a superior solution to a common computational problem.
> (Ditz & Nieder 2016: 8)

3.2. *Number Proper*

There are a lot of numbers out there but grammar marks only three: *singular, dual, trial.* Anything more is just *plural.* Aside from *plural,* the commonest number is *singular,* followed by *dual. Trial* is cross-linguistically rare, but found in Larike (Laidig & Laidig 1990), Wunambal (Dixon 2002:246), and Urama:

(9) *Urama*

	singular	*dual*	*trial*	*plural*
1P	mo	nimoiti	nimoibi	nimo
2P	ro	rioiti	rioibi	rio
3P	nu	niti	nibi	ni

(Brown *et al.* 2016: 20)

Verbs in Urama agree in number with their subjects, showing that the grammar proper makes use of it (from Brown *et al.* 2016: 27):

(10) a. Nu nahuai abodo ka.
3SG song sing PRESENT
'S/he is singing a song.'

b. Niti nahuai abodo ka=ido.
*3**DU** song sing PRESENT=**DU***
'They both are singing a song.'

c. Nibi nahuai abodo bi=ka=umo.
*3**TR** song sing **TR**=PRESENT=PL*
'Those three are singing a song.'

d. Ni nahuai abodo ka=umo.
*3**PL** song sing PRESENT=**PL***
'They are singing a song.'

No affix in any language marks 4 things, or 5, or 6.[6] These lie beyond grammar, presumably because they lie beyond vertebrate mathematics.

Corbett (2012: 120ff.) argues that apparent quadrals are actually *paucals* of which he distinguishes two kinds, one ≅ 3 (*paucal* proper), the other ≅ 4 (*greater paucal).* Such a distinction (singular/dual/paucal/greater paucal/plural) is found in Sursurunga (Hutchisson 1986); Corbett (2000) claims that a five-way number distinction like this is as much as any language allows. He also distinguishes a rare *greater plural,* which "may imply an excessive number or else all possible instances of the referent" (Corbett 2012: 120, citing Ojeda 1992 on Arabic). So it seems that 1/2/3 are the only precise *number* categories human languages mark grammatically, with one or two additional categories of *paucal* and *greater plural*, but nothing specific past 1/2/3, where numbering gives way to *more/most*, the domain of the ANS.

Hurford (1987: 111) notes that the "domain of grammatical number systems […] corresponds very closely to the very low numerosities which are recognizable by subitizing". Subitizing is the immediate apprehension of the exact number of items in small sets and tops out at 3~4 in vision (Kaufman *et al.* 1949), audition (Camos & Tillmann 2008), and touch (Riggs *et al.* 2006) for humans. Hurford notes that the 3~4 number in subitizing is also found in the number of arguments taken by a verb (2007: 88ff), linking it directly to grammar. Subitizing 3~4 objects is thought to be driven by short-term memory, also limited to 3~4 things (Cowan 2001); Cutini & Bonato (2012) link it specifically to visual short term memory in humans and other animals.

What does subitizing correspond to in animal cognition? A great deal of work has been done since Koehler (1951) reported that crows can count and "there is evidence that a (non-verbal) distinction between singular and plural is available to animals" (Stancher *et al.* 2013: 308). More generally, grammatical number corresponds very closely to the 'object-file system' (OFS) or 'parallel individuation' system (PI) found in infants and reported for a number of vertebrate species. The ability to subitize 3~4 items has been reported in chimps (Tomonaga & Matsuzawa 2002) and monkeys (Hauser *et al.* 2000; Beran *et al.* 2011; Elmore *et al.* 2011). The Hauser *et al.* study involves rhesus monkeys watching apple slices get put into a number of opaque containers. Importantly, they never see all of the slices at once and therefore cannot get the result simply by subitizing; they must *count* the apple pieces.

> The monkeys chose the container with the greater number of apple slices when the comparisons were one versus two, two versus three, three versus four and three versus five slices. They failed at four versus five, four versus six, four versus eight and three versus eight slices. (Hauser *et al.* 2000: 829)

These monkeys seem to code *singular, dual, trial, plural,* just like the grammars of Larike, Wunambal, and Urama. Similar results have been reported for a number of species of birds (Rugani *et al.* 2008; Hunt *et al.* 2009; Garland *et al.* 2012) and fish.

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[6] Baker-Shenk and Cokely (1996) claim that ASL has grammatical marking for 1–5, but 4 and 5 seem to be morphological compounds: 'You-four come over here!'.

In a shoaling experiment, Gómez-Laplaza & Gerlai (2011: 572) report that "the capacity shown by angelfish closely matches that attained by other fish species, in which the upper limit of spontaneous discrimination for small quantities seems to lie at three elements". The experiments in Dadda *et al.* (2009) involve sequential presentation of stimuli to mosquitofish, holding area constant so they have to rely on pure quantity. The results mirror those of the monkeys in Hauser *et al.* 2000: "[U]sing a method of 'item by item' presentation, we have provided the first evidence that fish are capable of selecting the larger group of social companions relying exclusively on numerical information" (Dadda *et al.* 2009: 346). Moreover, their findings suggest

> that mosquitofish can rely on multiple cues to estimate numerosity and that the preferential access to the numerical information over the non-numerical may be task- and context-dependent. To discriminate which of two mosquitofish shoals is more numerous is likely to be a complex endeavour. The fish within the shoals may be spaced out and often not simultaneously visible, fish frequently move within the shoal, can change orientation and occlude each other. In this condition it may be advantageous to encode multiple attributes of the stimulus (number, area, movement, etc.) and base number estimation on different combinations of cues depending on contextual variables such as structure of the environment, time available for choice, numerosity and numerical ratio of items. Indeed, recent studies on humans and non-human primates suggest that this may be a common situation. (Dadda *et al.* 2009: 347)

Utrata *et al.* (2012: 1) show that "wolves are able to make quantitative judgments […] even when alternative strategies such as paying attention to non-numerical properties such as the surface area or time and total amount are ruled out", though the authors were unable to determine whether this was due to a (*more/most*) approximate number system or to a (*singular/dual/trial*) object file system.

Agrillo *et al.* report on the ability of fish to discriminate smaller numerical differences (2 items from 3) in fish:

> Our experiments show that the ability of mosquitofish to discriminate among sets containing a different number of elements is not limited to the socio-sexual context […] but also applies to sets of abstract elements. They also indicate that mosquitofish can accomplish this task when all non-numerical perceptual variables are matched between the stimuli, thus strongly suggesting that teleosts [bony fish that can protrude their jaws, a class most fish fall into—CG], like mammals, possess true counting abilities, at least in the domain of small numbers. (Agrillo *et al.* 2009: 3-4)

In the article showing both ANS and OFS counting in undergrads and guppies, they suggest that "the evolutionary emergence of numerical abilities may be very ancient, possibly dating back to before the teleost-tetrapod divergence" about 400 mya (Agrillo *et al.* 2012: 7; cf. Piffer *et al.* 2012).

Reptiles have only recently been studied in terms of numerical abilities and the results are currently too mixed to draw any firm conclusions from. Petrazzini *et al.* (2017) found that ruin lizards (*Podarcis sicula*) were better at discriminating size than number, while a follow up study found essentially the reverse: Some lizards were able to discriminate number, but none was able to discriminate the area of two items (Petrazzini *et al.* 2018). They conclude that the "poor performance observed here using a methodological approach commonly used in other vertebrates, might suggest a limit in ruin lizards' quantitative skills, although we cannot exclude other factors that affected their accuracy' (Petrazzini *et al.* 2018: 5).

Invertebrates also show mixed results. A recent review concludes that bees and possibly other insects have basic numerical cognition to 3~4, but notes that there is as of yet no evidence for an ANS in insects (Skorupski *et al.* 2017: 7).

3.3. Number Bound with Person

Person and number have a close affinity in language: most of the world's pronouns are simple portmanteau combinations of the two, as the following show, from White Hmong:

(11) *White Hmong*

	singular	*dual*	*plural*
1P	kǔ	ɨ̂	pé
2P	kô	né	ně
3P	nɨ̀s	nkàɨ̂	làɨ̂

Surprisingly, perhaps, there is evidence that person and number bind together in animal cognition as well. Group decision making among social animals suggests that 1P can bind to dual and to plural. In the philosophical literature on humans the problem of such 'plural selves' is shown by the many terms for it including *shared cooperative activity* (Bratman 1992) and *plural subjects:* "One is willing to be the member of a plural subject if one is willing, at least in relation to certain conditions, to put one's own will into a 'pool of wills' dedicated, as one, to a single goal (or whatever it is that the pool is dedicated to)" (Gilbert 1989: 8).

Despite the ontological difficulties they create, 1PL decisions are made by many types of mammal including bats, canids, cetaceans, primates, and ungulates. For a herd to leave a feeding or drinking area, for instance, or for predators to coordinate their actions in hunting, requires group decisions: No animal constitutes a herd or a pack on its own. African wild dogs are a case in point: They require a *quorum* to leave for a hunt and signal their vote by sneezing. These

> sneezes, a previously undocumented unvoiced sound in the species, are positively correlated with the likelihood of rally success preceding group movements and may function as a voting mechanism to establish group consensus in an otherwise despotically driven social system. […] Our results contribute to a growing trend in the literature that finds voting mechanisms and quorum thresholds used in decision making processes across taxa.
>
> (Walker *et al.* 2017)

Group decisions are also made by flocks of birds, for example, when thousands of starlings shift midflight in response to a falcon and the response-wave propogates across the flock at a rate quicker than individual starlings can fly (Procaccini *et al.* 2011). In modeling how the members of a flock distribute themselves with respect to patches of food, Farine *et al.* (2014: 177) found that their "great tits relied more heavily on the decisions of conspecifics than heterospecifics", obeying the rules 'avoid sites below one-third' for conspecifics and 'avoid sites below one-half' for heterospecifics; this shows that the internal composition of 1P is important as well. Pettit *et al.* (2013) show how pairs of homing pigeons follow flight paths that are a compromise of those each has separately learned earlier, and at speeds that are a complex compromise of the normal speeds of each bird.[7]

1PL decisions are made by fish as well in shoaling behavior, when they group together with other fish, usually conspecifics. Sumpter *et al.* (2008) show, for instance, how small groups of sticklebacks collectively decide which leader to follow and show that larger groups make better decisions than smaller groups (in picking better looking leaders), explaining in part how group decision making evolves via natural selection:

> The quorum-response rule provides a simple and effective way of integrating information. Individuals watch the decisions of others before committing themselves to a decision. (Sumpter *et al.* 2008: 1776)

School size in shoaling behavior during spawning and migration can range to 250 million herring and span as far as 40 kilometers, through which a quorum decision wave can propogate in only tens of minutes (Makris *et al.* 2009); as in grammar, the exact number of 'plural' is irrelevant.

Social insects also make 1PL group decisions, including ants (Cronin & Stump 2014) and cockroaches (Amé *et al.* 2006). In bees, "a swarm's choice of a future home is broadly distributed among the scout bees, and […] this leaderless process of group decision-making consists of a friendly competition among the different groups of dancers representing the different potential nest sites" (Seeley & Visscher 2004: 104). Such behavior seems to involve the same 1PL representation as that found in grammar: *self plus some number of others*, usually conspecifics.

A possible precursor to group decision making in animals is found in bacteria (Waters *et al.* 2005), archaea (Charlesworth 2017), and fungi (Sprague & Winan 2006). It goes under the name *quorum sensing* and can come about where members of a colony need to do something in unison that no single cell organism can do on its own, like form a biofilm. Our mouths have millions of bacteria, for instance, which our immune system usually copes with; but the bacteria can join together and form a hard biofilm (plaque) that makes them nearly impossible to kill. Some bacteria can bioluminesce when they occur in great density and famously use this in a symbiotic relation with Hawaiian squid they live inside.

> [Their] environmental sensing system […] allows bacteria to monitor their own population density. The bacteria produce a diffusible compound termed autoinducer which accumulates in the surrounding environment during growth. At low cell densities this substance is in low concentration, while at high cell densities this substance accumulates to the critical concentration required for activation of luminescence genes. (Fuqua *et al.* 1994: 269)

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[7] Though the study involves only pairs of birds, it was designed to show flock behavior for any number of birds; this is not special dual behavior.

Quorum sensing like this allows single-cell organisms to function together somewhat like a multi-cell organism and may facilitate their actions as social beings: '[W]hereas bacteria have traditionally been thought of as simple, single-celled organisms, we now know that bacterial populations and communities commonly exhibit complex behaviors such as intra- and interspecific communication, kin discrimination, and cooperation" (Platt & Fuqua 2010: 386). Quorum sensing is a crucial part of this communication and cooperation.

When multiple bacterial species exist in the same environment "each species can distinguish, measure, and respond only to the buildup of its own signal" (Waters & Bassler 2005), so that quorum sensing can serve as a cell-to-cell communication system within bacterial species as well as across them (Xavier & Bassler 2003). Though we should not take the term too literally (Platt & Fuqua 2010), quorum sensing might well be a precursor to the approximate number system found in animals.

1DUAL decisions are also reported in animal cognition, though there is no evidence I know of that these are necessarily treated as separate from 1PL decisions. They go under the name *conspecific cooperation tasks* and require two animals to work together to solve a task that neither can solve alone. A rope pulling task that requires two animals to cooperate to get a reward (Drea & Carter 2009, hyenas) "has been used with a wide range of species, from ravens to elephants [chimpanzees, macaques, elephants, gray parrots, rooks, ravens, kea, and dogs], with many succeeding in solving the task after being initially trained individually to pull the tray out by pulling both ends of the rope together" (Marshall-Pescini *et al.* 2017: 11793, references omitted). Such tasks bind 1P and 2P into a 1DU inclusive, *you and I*, just as the group decision tasks above bind 1P and 2P into a 1PL inclusive. I know of no evidence in animal cognition for 1P combining with 3P to form a dual or plural *exclusive* of 2P, though I think the question has not been raised.

Summarizing, it seems that the exact numerical system of grammar (*singular, dual, trial*) is matched by the 'object-file system' or 'parallel individuation' system found in pre-linguistic infants and many vertebrates (modulo reptiles, where the results are not yet in). This vertebrate system may have developed from an earlier and less sophisticated system like the ones we see in invertebrates or the quorum sensing found archaea, bacteria, and fungi.

3.4. *Zero*

No language to my knowledge has an affix indicating zero number. It is easy to imagine a language where zero is marked distinctly from singular, dual, and plural. Consider such a made-up language—'Pseudo-Greek', by adding a zero row to the Greek pattern from (8) above:

(12) *Pseudo-Greek*

	'citizen'	'soldier'	'son of Atreus'
zero	*polí:t–e:*	*stratió:t–e:*	*atreíd–e:*
singular	polí:t–e:s	stratió:t–e:s	atreíd–e:s
dual	polí:t–a:	stratió:t–a:	atreíd–a:
plural	polî:t–ai	stratiô:t–ai	atréid–ai

In Pseudo-Greek, *polí:t–e:* would mean 'no citizen' and a verb that agrees with it might show agreement distinct from singular, dual, and plural agreement. Again, no such language exists as far as I can determine. In actual Greek, zero counts as grammatically *singular*, as we can see with the agreement on the verb:

(13) oud–êìs ekoimé:tʰ–e
not–one slept–3SG
'noone slept'

The same obtains in English, where the verb in *noone sleeps* is 3SG. Grammar treats *noone, nobody,* and *nothing* as *less than two*: We find *noone is here, nobody is coming, nothing is worthwhile*. That is, grammar treats homespun words for zero as part of the ANS, where they are less than two, three, four, etc. Grammar does not treat these words as a special category alongside *singular, dual, trial,* that is, as part of the object-file system.

Historically, the notion *zero* is a recent mathematical discovery from 7th century India and languages that have borrowed this word treat it like 2, 3, or 4: *Zero children are here, *Zero child is here*. Languages may have a (borrowed) *word* for zero, but there is no grammatical category for it; it is just one of the things less than two. (For a formal analysis of the difficult semantics of *zero*, see Bylinina & Nouwen, to appear.)

Animals also seem to treat zero as nothing rather than as zero in the mathematical sense. The facts are not decisive (or many), but they are suggestive. Brannon *et al.* (2009) provide experimental evidence that monkeys have a *precursor to zero* based on the approximate number system discussed earlier. In one experiment, monkeys were able to match empty sets to empty sets, just as they were able to match sets of 2 to sets of 2, or sets of 6 to sets of 6; and when they did so they showed distance effects, such that an empty set was less likely matched to a set of 6 than to a set of 2. This is a more/most effect. In a second experiment, monkeys were taught to order smaller and larger sets; when they were tested on empty sets they tended to treat them as smaller than sets of 1, 2, 3…9. They summarize their results: "Overall, these findings demonstrate that the ANS can support representations of empty sets and these representations may serve as a precursor for the ability to represent symbolic zero" (Brannon & Merritt 2011: 215).

The same has been found for honey bees, using a task in which honey bees were taught the notions 'greater than' and 'less than' and then had to apply them to novel situations that included the empty set, e.g., to rank an empty visual set as less than one that contained one or more dots.

> Our findings show that honey bees can learn and apply the concepts of greater than and less than to interpret a blank stimulus as representing the conceptual number of zero and place zero in relation to other numerical values. Bees thus perform at a level consistent with that of nonhuman primates by understanding that zero is lower than one.
>
> (Howard *et al.* 2018: 1126)

This supports an ANS in monkeys that can compare empty sets with larger sets, a 'precursor' to the full idea of zero. If animals lack the full ability to represent symbolic zero they may be in line with human grammar, which lacks means for expressing zero as well.

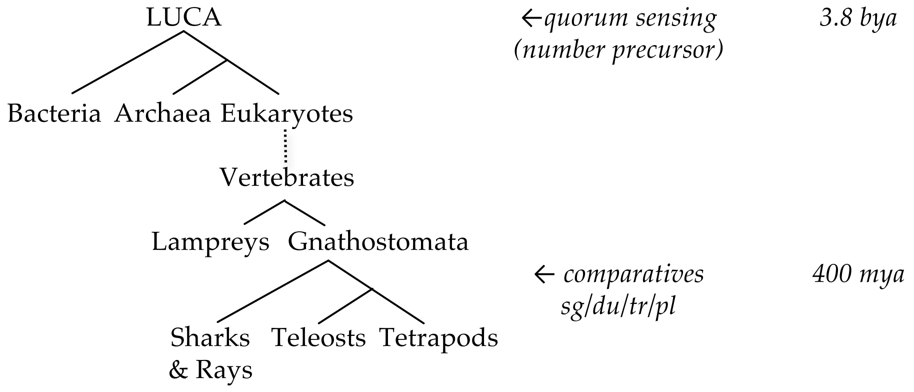

Figure 2: Possible age of number.

4. Gender

Morphologists generally use the term gender to mean ‘kind’, as befits its Latin root, and it is usually abstract, so that all nouns are shoe-horned into categories based on a few semantic categories. Most languages do not distinguish different kinds of noun, but those that do use one of two criteria:

> From our sample, of the languages with a gender system, the majority—84—have sex-base gender systems, compared with 28 with systems with the other possible basis, namely animacy. This is a remarkably clear result, with a surprising disjunctive pattern: gender systems are based on sex or on animacy. (Corbett 2012: 113)

4.1. Sex-Based Gender

Up to a third of languages grammatically encode gender systems based on the sex of the referent, with inanimates assigned randomly to the male or female class. As Dahl points out:

> The pervasiveness of sex as gender criterion is striking. There are many possible ways of classifying animates, in particular human beings, that might be used as a basis for gender, such as social status, ethnic origin, profession, age, hair color, etc. but none of them except perhaps age seems to play any important role in gender assignment. (Dahl 2000: 102)

If grammatical categories marked what was important to people, we might expect genders based on profession, age, and hair color. But such categories are lacking in grammars of all languages, probably because they are not deeply enough embedded in the representational systems we share with most vertebrates: Only pieces of this system seem to be coded grammatically.

Ancient Greek can again serve as an example of how a language assigns words to genders. Words with male referents (*man, boy*) in Greek are almost always grammatically masculine, words with female referents (*woman, girl*) are almost always feminine: This makes it a sex-based gender system and words like *anḗr* ‘man’ and *gúnē* ‘woman’ are said to have ‘natural gender’. Words with sexless referents (*speech, island, wall,* etc.) can be of any grammatical gender and some diminutives (*manikin, child*) are grammatically neuter even though they have male or female referents.

(14) *Ancient Greek*

masculine	anḗr ‘man’	kóuros ‘boy’
	pátrōn ‘uncle	huiós ‘son’
	lógos ‘speech’	háls ‘salt’
	ánemos ‘wind’	dáktylos ‘finger’
feminine	gúnē ‘woman’	kórē ‘girl’
	tʰeía ‘aunt’	tʰugátēr ‘daughter’
	nêsos ‘island’	náus ‘ship’
	pétra ‘rock’	sîgma ‘letter S’
neuter	téikʰos ‘wall’	álgēma ‘pain’
	hydōr ‘water’	álpʰa ‘letter A’
	antʰrṓpion ‘manikin’	gúnaion ‘little woman’
	teknon ‘child’	andrápodon ‘captive’

(Smyth 1920: §197)

Other elements in the noun phrase agree with the noun in gender, a grammatical phenomenon known as *concord*:

(15) a. ekéin-**os** kóur–**os** esti kʰarí–**eis**
DEM–MASC boy–MASC is elegant–MASC
‘That boy is elegant.’

b. ekeín-**ē** kór–**ē** esti kʰarí–**essa**
DEM–FEM girl–FEM is elegant–FEM
‘That girl is elegant.’

c. ekéin-**o** eídōl–**on** esti kʰarí–**en**
DEM– NEU phantom–NEU is elegant–NEU
‘That phantom is elegant.’

Animals presumably have no *grammatical gender* because they presumably have no nouns or adjectives. The question here though is whether they process sex and animacy in their lives. The sex part is simple: Plants and animals that reproduce sexually obviously process information about male and female; sex goes back to the last common eukaryote (Goodenough & Heitman 2014). Most animals and all vertebrates reproduce sexually, a point I will not belabor, so male and female are very old categories; neuter is as well, if only by default.

More surprising is that partner preference is not marked grammatically in any language. Grammar never marks who you prefer to have sex with, or even whether you have sex, just whether you are biologically male or female. This despite the clear importance of sexual preference to most people. It is not clear how sexual preference works in animals: "Spontaneous homosexual behaviour, defined as exclusive same-sex sexual preference, appears to be rare in animal species despite the fact homosexual behaviours (mounting or being mounted by a subject of the same sex) are frequently seen in hundreds of species when congeners of the opposite sex are not (easily) available" (Balthazart 2016: 4). For homosexual practice in the animal kingdom generally, see Bagemihl (1999). In any case, the rich notions of sex that humans deal with are ignored by grammar, which treats sex as a simple binary opposition, more along the lines of how other animals seem to treat it.

4.2. Animacy-Based Gender

Animacy is the other common grammatical gender, though animacy proper is often conflated with whether something is human or not (Ortmann 1998). Clear cases of grammatical animacy are well-studied in Algonquin languages, where all nouns are either animate or inanimate grammatically. Blackfoot noun roots serve as illustration. While some grammatically animate nouns (*knee, wagon, aspen*) are inanimate in the real world, all things that are animate in the real world are grammatically animate:

(16) *Blackfoot*

animate	ninaa 'man'	aakii 'woman'	omitaa 'dog'
	mottoksis 'knee'	áinaka'si 'wagon'	siikokiína 'aspen tree'
inanimate	awó'taan 'shield'	naapioyis 'house'	miistak 'mountain'

(Wiltschko & Ritter 2015: 873)

The grammatical relevance of animacy shows up in how plurals are marked, *–iksi* for animates, but *–istsi* for inaminates. Note that the demonstrative agrees with the noun it modifies:

(17) a. om–**iksi** saahkomaapi–**iksi** iik–sspitaa–yi–aawa
DEM–PL boy–PL INTNS–be.tall.AI–PL–3PL.PRN
'Those boys are tall.'

b. om–**istsi** naapioyis–**istsi** iik–sspii–yi–aawa
DEM–PL house–PL INTNS–be.tall.II–PL–3-PL.PRN
'Those houses are tall.'

(Bliss 2013: 31)

Humans can tell biological motion from non-biological motion even with just limited points of light to represent it (Johansson 1973), so the animacy in grammar draws on part of our biology. The ability to detect animacy is innate in humans and is not limited to detecting humans:

> [N]ewborn babies are able to discriminate between two different point-light displays depicting either biological motion or nonbiological (random)

> motion and they manifest a spontaneous preference for the biological motion display even if it depicts an unfamiliar shape such as a walking hen. Even more interestingly, the results demonstrated that the preference for biological motion was orientation specific. Newborns were shown to prefer upright compared with inverted biological motion displays.
> (Simion *et al.* 2008: 811)

The ability to pick out animates is also innate in newborn chicks, who prefer film clips of lights strapped to walking hens over film clips of lights strapped to hens that twirl around rigidly or of lights moving about randomly:

> Intriguingly, the preference was not specific for the motion of a hen, but extended to the pattern of motion of other vertebrates, even to that of a potential predator, such as a cat. The predisposition found in the present research for certain kinds of movements shares characteristics in common with the predisposition for aspects of form. […] Visually inexperienced chicks prefer the head and neck region of a hen to artificial objects. Similar to this preference for form, the preference for movement is not species specific. Evolution seems to have equipped the visually inexperienced bird with a sophisticated set of detection systems. (Vallortega 2005: 1312)

Similar experiments have found this detection system in a number of vertebrate species including cats (Blake 1993), bottlenose dolphins (perhaps, Herman *et al.* 1990), female marmosets (Brown *et al.* 2010), and fish (Nakayasu & Watanabe 2014, Schluessel *et al.* 2015). Troje & Westhoff found that for some animals this is related to the perception of moving *feet.* They tentatively

> argue for an innate and possibly evolutionary old mechanism that the human visual system shares with other animals. The observation that it is relatively easy to get close to wild animals in a car, a canoe, or a similar vehicle might be due to the absence of the typical movement of feet. Similarly, the creeping movement of a hunting cat can be interpreted in terms of disguising the ballistic component in its locomotion. Our findings about the role of the feet as a cue to the direction of motion of scrambled point-light displays support the notion of such a general 'life detector'.
> (Troje & Westhoff 2015: 823)

Such abilities in various species support "the hypothesis that detection of biological motion is an intrinsic capacity of the visual system, which is presumably part of an evolutionarily ancient and non-species-specific system predisposing animals to preferentially attend to other animals" (Simion *et al.* 2008: 809).

Some animals clearly detect *conspecific* motion. Japanese rice fish (medaka, *Oryzias latipes*), for instance, only shoal and school with conspecifics and thus must be able to detect them. It has been shown that they can recognize conspecifics from biological motion alone. In a recent study, Shibai *et al.*

> decomposed the biological motion of medaka into either posture or motion-trajectory elements, where the 'posture' element contains information regarding body-shape-level motion (also known as 'body motion') and the 'motion-trajectory' element contains information regarding entire-field-level motion (also known as 'locomotion'). We prepared visual stimuli that contain both, either, or none of those elements, using point-light stimuli; then,

> we presented the stimuli in separate experiments to determine the contribution of each element to the attractiveness of biological motion. We found that each of the two elements alone exhibited a significant degree of attractiveness […]. (Shibai *et al.* 2018: 2)

Animals generally recognize conspecifics as an important subset of the world, of course, usually using pheromones and the like rather than biological motion. A grammatical version of this occurs in languages that treat the category *human* as a special class of *animate* in agreement systems (see Ortmann 1998). Conspecific identification is probably universal among vertebrates and occurs from bumblebees (Dawson & Chittka 2012) to trees (Dong *et al.* 2017). Bacteria (Wall 2016) recognize kin as well, though the species/self distinction is blurred or lost for things that reproduce by fission:

> Bacterial kin recognition involves three steps. First, individuals recognize one another by receptor-ligand or receptor-receptor binding. Second, recognition leads to a signal or biochemical perception. Third, there is a behavioral response […]. [B]acterial kin recognition involves a molecular event(s) that can be directly observed—e.g., kin cells that adhere together. The end result of these interactions is a cooperative behavior that increases the fitness for the participating individuals. (Wall 2016: 2)

Kin recognition is essential to things like biofilm formation and quorum sensing, both of which are found in archaea as well as bacteria and eukaryotes. If archaea also recognize their kin, as seems likely, it could go back to LUCA (Fig. 3).

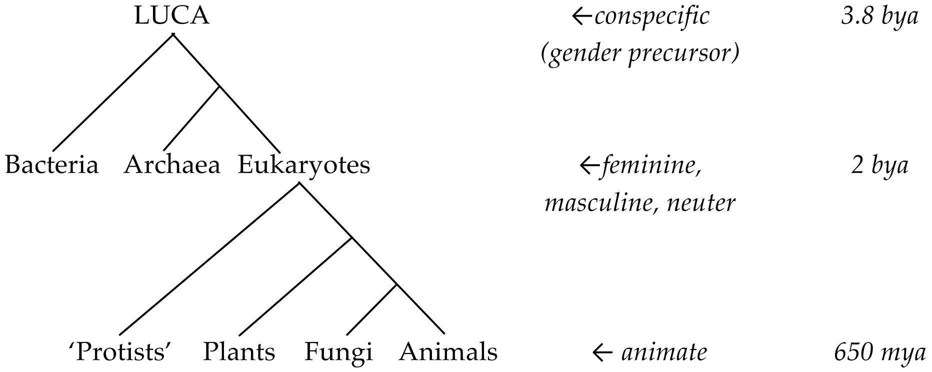

Figure 3: Possible age of gender *('Protists' shown as a group for simplicity).*

5. Conclusion

A recent book on the evolution of language states that the semantics of morphemes in natural language are not well understood:

> The atomic elements pose deep mysteries. The minimal meaning-bearing elements of human language—wordlike, but not words—are radically different from anything known in animal communication systems. Their origin is entirely obscure, posing a very serious problem for the evolution of human cognitive capacities, human language in particular.
> (Berwick & Chomsky 2016: 90)

I hope to have shown that the origin of a small subset of these atomic elements poses no such mystery: The origin of the ϕ-features that make up person, number, and gender seem quite clear. They have no analogues in animal communication systems but they do have clear analogues, often exact homologues, in the biological systems common to vertebrates, animals, even plants and single cell organisms. They predate humans by millions of years, as Bickerton (1990) and others suggested decades ago, and their semantic content remains unchanged.

Fig. 4 summarizes the evidence for animal use of the ϕ-features behind person, number, and gender, with an approximate age for each, mapped onto the recent chronology of life forms in Knoll & Nowak (2017). A precursor to person seems to have arisen very early among bacteria and archaea in *self-referencing*, required for immune systems. If we can associate person proper with *self-awareness*, it may trace back to animals generally. The likely precursor to *gender* is the detection of conspecifics, found already in bacteria and possibly archaea. *Sex*-based gender originates with eukaryotes 2 bya and *animacy*-based gender with animals 650 mya. *Quorum-sensing* is the likely precursor to number and traces back deep into bacteria; *number* proper (*more/most*, SG/DU/TR/PL) probably does not occur before vertebrates, about 400 mya.

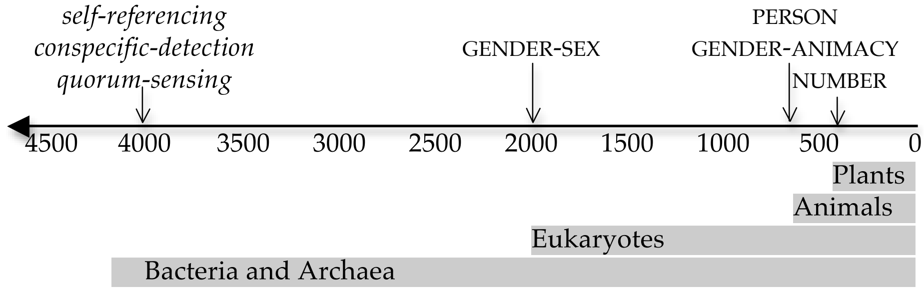

Figure 4: Approximate ages of ϕ-features (in mya).

In other work I argue that the verbal notions tense, mood, and aspect are also shared with animals, as are the thematic roles that link nouns to verbs (Golston 2018). I hypothesize more broadly that the semantics of all grammatical categories are used in animal cognition and that nothing of the semantics of grammar is unique to humans; grammatical categories like these have been called “the flesh and blood of grammar” (Ouhalla 1991/2005: 4–5).

It is increasingly clear that our representational systems are shared to a great extent with those of other animals, especially vertebrates. I hope to have shown that a number of core grammatical categories, the ϕ-features, are built directly on representational systems we share with others. We are probably unique among animals in *communicating* with ϕ-features, but we are probably not unique in *thinking* with them.

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★ FORUM ★

Notice

2018 was no less busy at *Biolinguistics* than previous years. Apart from the new volume collected here (as well as several ongoing review processes of new manuscript submissions), this year saw the completion of the Special Issue on the 50th anniversary of the publication of Eric Lenneberg's *Biological Foundations of Language*, expertly guest-edited by Patrick Trettenbrein. *50 Years Later: A Tribute to Eric Lenneberg's Biological Foundations of Language* can be downloaded from https://www.biolinguistics.eu/index.php/biolinguistics/issue/view/30.

Towards the end of the year, Noam Chomsky celebrated his 90th birthday. And while *Biolinguistics* did not do anything special, it is quite clear that without Noam Chomsky there would arguably be no 'biolinguistics' (or, as the special issue showed, in juxtaposition with Eric Lenneberg). But Michael Schiffmann, a long-standing supporter of *Biolinguistics*, put together a wonderfully informal festschrift on this occasion, *Revolutionary New Ideas Appear Infrequently (Or Don't They?)*, which can possibly be obtained directly from him (mikschiff@t-online.de).

The biggest changes for the journal concern operational issues, however. We recently completed migration to full compatibility with the latest version of Open Journal Systems (and are working hard to overcome teething problems). Ideally, there will be no relevant backlash for readers, authors, and reviewers—but if you experience any unwelcome challenges, please do get in touch with a simple email to kleanthes@biolinguistics.eu or kleanthi@ucy.ac.cy.

We also implemented editorial changes, where yours truly as Editor-in-Chief will from now on be supported by four capable Associate Editors:

- **Maria Kambanaros**, Associate Professor of Speech Pathology in the Department of Rehabilitation Sciences and Director of the Neurorehabilitation Lab at Cyprus University of Technology, will be in charge of submissions within the areas of language pathology and covering clinical issues;
- **Evelina Leivada**, Marie Skłodowska-Curie Postdoctoral Fellow at UiT–The Arctic University of Tromsø and member of the Cyprus Acquisition Team (CAT Lab) as well as the research centers Language Acquisition, Variation & Attrition (LAVA) and Acquisition, Variation & Attrition (AqVA), will be responsible for psycho- and experimental linguistics;
- **Patrick C. Trettenbrein**, PhD student in the Department of Neuropsychology at the Max Planck Institute for Human Cognitive & Brain Sciences in Leipzig, will handle all things concerning neurolinguistics and cognitive neuroscience of language; and
- **Bridget D. Samuels**, Senior Editor for the Center for Craniofacial Molecular Biology at the University of Southern California, will cover all submissions relating to phonology and language evolution.

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In addition to the website transition and the instantiation of our new core editorial team, we are also reworking the layout of how the published goods are going to look in the future. One of the latest innovations we are implementing is the introduction of Registered Reports in 2019—alongside Articles, Briefs, Reviews, and Forum contributions, as well as the occasional Editorial. Registered Reports will be reviewed over two stages on the basis of a detailed study protocol prior to the actual research to be carried out (see this external link for more, which will be adapted to *Biolinguistics* very soon: https://cos.io/rr).

Lastly, a big thank-you to all the reviewers that have served *Biolinguistics* throughout 2018. They are listed below by name (in alphabetical order). For everything else, I thank all supporters as well as the members of the *Biolinguistics* Advisory Board, the Editorial Board, and the Task Team that are not specifically mentioned by name for active participation and constructive feedback all the way through. Next year's notice will come from an even stronger editorial team.

Reviewers

Sergio Balari
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