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Review article

Language and imagination: Evolutionary explorations☆

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ABSTRACT

This article provides a functional analysis of the conditions for language to emerge, and analyzes its role in imagination. It starts with some initial reflections on imagination and its evolutionary beginnings in relation to the role of working memory and tool use by chimpanzees and humans up to modernity. It then presents an analysis of what it takes to develop language, and how language gives rise to higher orders of imagination. An important theme in the discussion is which of the changes in the development leading to language may have been gradual and which changes must reflect a discontinuity. It concludes with a paradoxical property of imagination: One part of our mind is able to imagine and create systems that another part of our mind is unable to deal with. It shows how this tension manifests itself in the notion of an impossible language, but crucially also in conceptions of human society at large.

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☆ This contribution originated as an invited lecture for Master students of the Faculty of Humanities of Utrecht University in 2011. It put certain ideas about language and imagination from Reuland (2010) in a broader context. The idea of writing it up as an article kept lingering for a while until I received Johan and Martin's kind invitation to submit a contribution to the volume on the biology of language they were planning. Right after I finished the first draft in January 2016, I saw that Bob Berwick and Noam Chomsky just published a new book *Why only Us: Language and Evolution*. As one may expect, there is a certain amount of overlap; neverthess, the focus is different enough, as the reader wil see. Time is lacking to do justice to their insights; occasionally, I will point out a relevant link, though. This contribution profited from comments on various versions through time. When I first presented it, I got valuable comments from the students in the audience. Fred Coolidge and Andrea Moro were so kind to send me very helpful comments on the original presentation when I sent them the pdf. I am very much indebted to Bob Berwick, Denis Delfitto, Loes Koring, Marijana Marelj, Lyn Wadley, and Yoad Winter for their comments on the prefinal version of the current contribution. Comments from two anonymous reviewers were very helpful in broadening the perspective and sharpening the argument. And many thanks go to Martin Everaert for leading me through the final stages. All errors are my own. On a final note, for sake of illustration various pictures found on the internet have been used. It was not always possible, though, to trace the original source. Sources for the pictures include: Picture 1 http://www.visual-arts-cork.com/prehistoric/blombos-cave-art.htm; Picture 3 http://humanevolutionb36.weebly.com/cultural-evolution.htmlhttp://pages.ucsd.edu/~dkjordan/arch/tools.html; Picture 4 http://www.mcescher.com/gallery/back-in-holland/other-world/; Picture 5 https://quizlet.com/24728420/arh-2050-midterm-prehistoricneolithic-flash-cards/; Picture 6 https://www.eyeonspain.com/blogs/bestofspain/16047/altamira—prehistoric-masterpiece.aspxhttp://www.art-prints-on-demand.com/a/hieronymus-bosch/the-garden-of-earthly-del-11.htmlhttp://metamorphosisofnarcissus.blogspot.nl/; Picture 8 Le Corbusier, The Radiant City: Elements of a Doctrine of Urbanism to be Used as the Basis of Our Magine-Age Civilization (1933) http://florenciabenedetich.blogspot.nl/2012_09_01_archive.html.

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1. For starters

Every scientific inquiry begins with wonder. We are so used to our ability to imagine states of affairs that differ from what the world around us shows us, and to work towards getting them realized that we tend to take it for granted. But, what underlies this ability? To what extent are we unique in this ability? And how did it arise? These are the question that started intriguing me at some point.

The source of my fascination is what seems to me a paradoxical property of imagination. One part of our mind is able to imagine and create systems, sometimes actually realized in our environment, that another part of our mind is unable to deal with. Being a linguist, I first became aware of this tension in the notion of an impossible language in Chomsky (1965). But looking carefully, one can see it in many other domains. It is this paradox that kept fascinating me, and I hope to be able to convey some of this fascination. Let me start with some initial reflections on this topic. Then I take you to what one may consider the evolutionary beginnings of imagination. After that we will discuss two significant leaps in its development, one intrinsically connected with language. I will end with a discussion of the paradox I mentioned. An important theme in my discussion is which of the changes in our development may have been gradual – just more of the same – and which changes must reflect a discontinuity.

Blombos Cave in South Africa is famous because it has been found to contain some of the oldest traces of human imagination, dating from some 100.000–70.000 years ago, as in Picture 1, which shows some of the products of such imagination.[1]

These traces can be argued to represent Imagination in a most modern sense: results of imagination freed from the use in the direct struggle for life with the natural environment.

What we see is shells with holes that are clearly artificial, a piece of ochre with engravings. Even if we don't know for sure why the holes were put in the shells (to make beads; for some other reason?), or why these lines were made on the ochre, we do know that they were put there by a purposeful mind, a mind with a plan, working towards a situation that did not yet exist in the outside world, but was already represented in a mental world; indeed a result of imagination.[2]

[1] There is a rich literature on the earliest indications of what one may broadly call 'symbolic behaviour;' as a mark of modern 'humanity, see for instance, Henshilwood et al. (2002); d'Errico and Henshilwood (2011), Henshilwood and d'Errico (2011a,b), Wadley (2010, 2011), and references cited there. (See also Botha (2010) for critical discussion of the inferences to be drawn.) These authors put the earliest traces in Blombos Cave at 70–100 ka BP. Note, that henceforth I will mostly be using the unit *ka*, where 1 ka stands for 1000 years, and BP stands for before present. For present purposes the sketch I present in the main text will suffice.

[2] As Lyn Wadley (personal communication) notes, other artefacts and items could equally be used. She suggests that it is useful to distinguish betweeen the imaginaton of **the individual** whose idea it was to collect small sea shells, perforate them and use them for ornaments, and the imagination of the majority of consumers of

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Picture 1. Beads and ochre.

Reflecting on imagination is not new, see already Wallace (1871). In 1967 Jacob Bronowski (1967) wrote an essay on this subject – *The Reach of Imagination*. As he wrote, *"To imagine* means to make images and move them about inside one's head in new arrangements." More prosaically this means that imagination involves the *manipulation of mental representations.* However, as we will see in our subsequent discussion (Section 6 ff), the notion of an image will have to be fundamentally extended beyond what Bronowski had in mind, to cover not only visual/perceptual but also language mediated – propositional – imaging (see, for instance, McGinn 2004; Beaney, 2005, Gaut, 2010, to mention a few contributions from the extensive literature). Note, furthermore, that mental representations in the sense intended need not be visual. Nothing in the initial intuition prevents mental representation of sounds being created and manipulated – although this possibility did not receive a prominent role in the discussion

Importantly for now, if we are to have manipulation of images, we need a space in which these manipulations can be carried out. Limits on this space will limit imagination, and the use we can make of its results. This immediately connects the study of imagination to the study of mental work spaces: the study of *working memory* (WM).[3]

A sketch of its organization in modern humans is given in Picture 2, from Baddeley (2007, synthesizing previous work). It represents an influential functional analysis of a memory system for mental representations, with four main components:

- Visuo-Spatial sketch pad
- Phonological loop
- Episodic buffer
- Central executive

From these, the Visuo-Spatial sketch pad is taken to be involved with non-linguistic images, whereas the Phonological loop is held to be most directly involved with language. It is the system that is involved in the rehearsal strategy one uses for maintaining lists of unrelated elements, for instance when shopping.[4] It is interesting since it provides an indication that the form aspect of linguistic units plays a crucial role in the way our cognitive system handles linguistic units. For current purposes we need not go into the details of the model, as most labels are self-explanatory.

Part of our exploration will be devoted to aspects of imagination that are beyond immediate observation, either since it involves long-past stages in human development, or properties that are still out of bounds for our observation techniques. Although this entails sharp limitations on what can be said with any certainty, it doesn't entail that nothing can be said with certainty. A method that does enable us to draw non-trivial conclusions is a *functional analysis*. Such an analysis is based on what it must have taken to realize certain '*products' of imagination*.

If we see that a certain system can produce particular outcomes, from tables to cars, or from watches to laptops, this tells us something about the properties the system must minimally have. This equally applies to mental systems. If we observe that an organism has been able to carry out plans, working towards the realization of a mentally represented state of affairs, this tells us something about its capacities for imagination: Given that such a system is/was able to perform certain operations on representations, what are the minimal properties it must have (had)? A functional analysis abstracts away from the particular processes taking place in the brain. And, of course, in the end, to obtain a full explanation such connections must be established, but for now a functional analysis will (have to) do. Bronovsky's idea that imagination involves forming new arrangements presupposes that mental representations are analyzable into component parts. This idea provides the basis for the subsequent discussion. To do so, let's first consider the notion of an 'image' or 'mental representation'.

2. Mental representations

There is a philosophical tradition in which one can ask deep questions about the nature of representations. What does it mean for x to be a representation of y, and not of z? Is x a true representation of y or not, etc.?[5] The literature provides extensive discussions of these philosophical issues (for instance, Burge, 2010), but for our present purposes they can be abstracted away from, since they only arise in the context of human intentions. Our starting point can just be this: Inputs from sensory systems emanating from some outside source cause bio-chemical changes in the internal state of organisms (in a part that often, but not always, corresponds to a brain). Such changes may be very elementary, as for instance in the case of fan worms (with a multitude of 3-cell receptor systems, acting as burglar alarms rather than imaging eyes, as Nilsson (1994) puts it). And in fact, the resulting change may be neutral to distinctions as visual, auditory, olfactory, etc. In mammals, on the other hand, there is specialization, as in the form of a topographically organized visual field (Van Essen et al., 1984; as an example of an early study). For instance, in the case of macaques that have been 'sacrificed' after receiving a particular visual input, we can see the effects of such changes as a visible pattern in their brains like an imprint of that input.

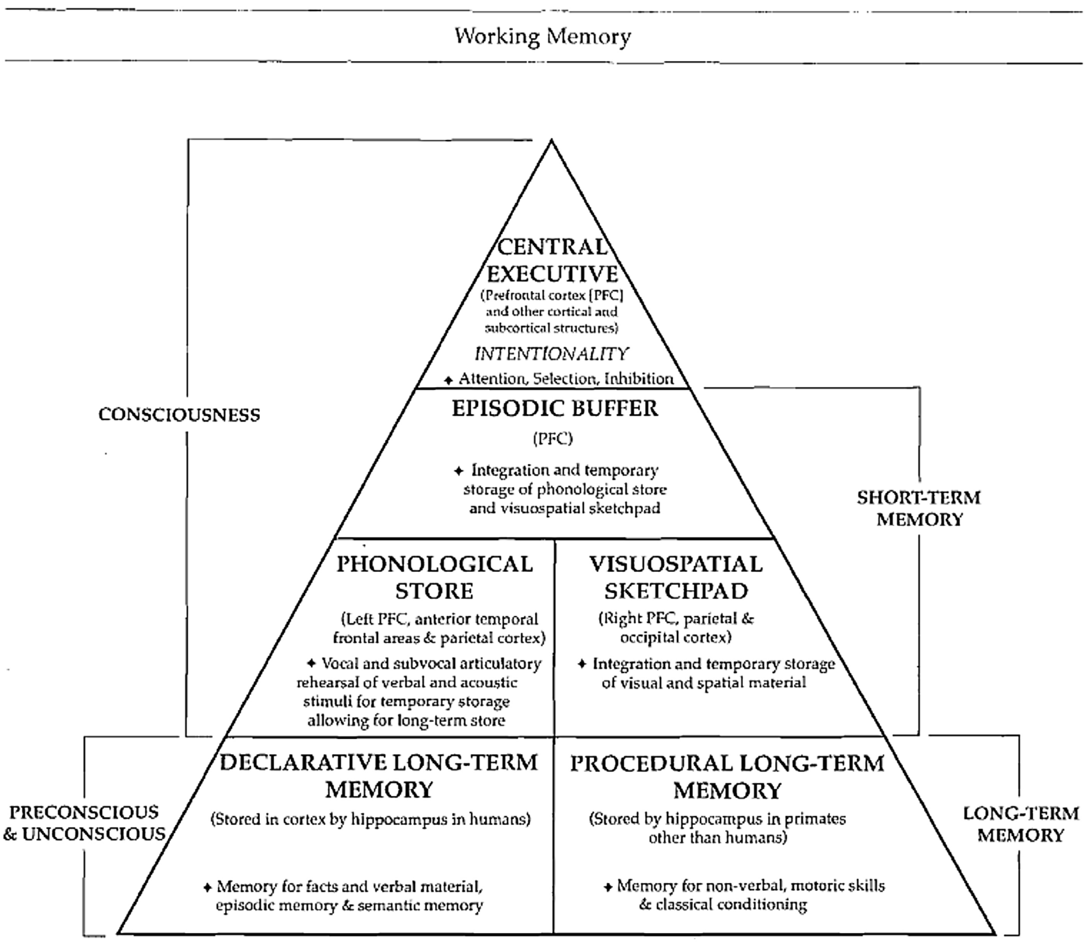
Thus, for now it is enough that we can observe bio-chemical differences in a brain on the basis of some input – visual, auditory, olfactory – that persist for some time (from seconds to years), and call these *representations* of that input. There are vast differences

the beads. Their imagination may not have been involved as much as a desire for conformity to the "fashion" of the time. Indeed, in any case of cultural innovation it is important to distinguish between inventors and followers. As she further notes, the small perforated shells were utilized not just at Blombos, but also at Klasies and Sibudu (Sibudu is more than 1000 km from Blombos and the beads are contemporaneous), so the "fashion" seems to have spread quickly and far. This suggests that the beads expressed meaning that was socially important across a wide area. In fact, the concept of the perforated beads may be taken to a different level by someone other than the inventor of the bead concept.

[3] Baddeley provides a state-of-the art summary of the theory of working memory in his 2007 book (Baddeley, 2007). Coolidge and Wynn (2005) and subsequent work develop an interesting perspective on human cognitive evolution in these terms. Although prima facie the notion of working memory is rather intuitive, it is actually the subject of considerable debate (see for instance, Beaman, 2010). Much depends on the way in which particular information is encoded. For current purposes however the intuitive version in Baddeley (2007) suffices.

[4] It is also the component associated with Miller's (1956) magical number 7 ± 2 as an indication of the number of unrelated items one can simultaneously hold in short term memory. Again an issue of considerable current debate.

[5] Thanks to one of the students in my audience for bringing this issue up and stimulating me to sharpen the discussion.



Picture 2. Working memory.

across organisms in the details of the input that can be encoded, and note, that any object has infinitely more properties than can be encoded. So, representations are not true or false, they are just more or less detailed, and perhaps more or less effective in the quest for survival of its carrier.

To say that an organism has imagination, is then to say that its brain has operations affecting initial representations, yielding brain states of a similar type that did not directly result from a sensory input.[6]

For an organism to have imagination in this sense comes down to: i. The capacity to maintain mental representations over time; ii. the capacity to access and maintain alternative representations simultaneously; iii. an articulation/analysis of representations allowing manipulation/operations on sub-parts, that is, a parsing ability (see Byrne 2006).

Thus, having imagination is not by definition a human trait. However, imagination may manifest itself in qualitatively different ways, varying from being so trivial that one would hesitate calling it that, to being so rich, that calling it 'imagination' feels quite proper. We will see in Section 6 ff., what has to be added to arrive at a mode of imagination including language (or what one may refer to as 'propositional thought').

I will take my starting point in some initial – and not very sophisticated – observations about dogs, and then make the by now almost inevitable move to chimpanzees. On the basis of that discussion we may move to (early) humans.

2.1. Hunter on dogs

Bronowski reports research carried out by the American psychologist Walter S. Hunter around 1910 on the memory capacity of dogs. In Hunter's experiment the dogs would face a number of tunnel openings. When a light went on in a tunnel, the tunnel would open and there would be food for them to obtain. The idea was that they would run towards a tunnel as soon a light was on, but not to tunnels without a light. They were quite good at this. The task was then made harder. There were three tunnels, and the dogs were made to wait for some time until after the light went out again. Dogs are quite good at all kinds of memory tasks, but this task apparently requires (access to) a kind of memory system that is less well developed. They failed if they were restrained and had to wait for more than a few seconds after the light went out. That is, the mental representation 'x is a tunnel with light' decays rapidly after the stimulus disappears. This indicates that dogs only have a very limited ability to keep visual stimuli active.

Hunter's is an old study. But more recent work (Fiset et al., 2003; Fiset and Doré, 2006) confirms Hunter's picture of dogs' abilities, and, in fact, the same applies to cats'.[7]

[6] Beaney 2005 observes that one must be careful to distinguish the result of imagination from memories; note, however, that memories can in fact be imaginary; so what counts must be whether the locally stored state is altered as a result of the retrieval process.

[7] In other domains dogs have a much better memory, of course: they recall their house (and are able to find it back after having been transported over long distances), they know their masters and other members of the household, obey commands, etc. This is testimony to the well-known fact that there are different types of 'memory'

2.2. From dogs to chimpanzees: a huge step

I now take a huge step from dogs to chimpanzees. Chimpanzees are well-known for their ability to use simple tools, and for our persisting attempts to teach them human language. Although they have a surprising ability to handle abstract symbols they have not been able to acquire language in our sense (Terrace et al., 1979), perhaps not so surprising, as Noam Chomsky has remarked time and again, since they aren't us. Here we will primarily limit discussion to certain aspects of their tool making.

2.2.1. Some notes on tools

What chimps can do is impressive as compared to other animals' standards. Stories about their capacities in captivity abound in the literature. Here I will limit discussion to tool use in the wild. Sanz and Morgan (2007) report on their use of tools in catching termites. They use branches to probe into termite nests, getting them out full of termites clinging to them. However, some types of branches work better than others. For an optimal result they modify branches by chewing on them, and thus producing branches as tools that fit the requirements. However, they have not been observed making complex tools, for instance by attaching a sharp stone to a stick (to be distinguished from making composite use of simple tools, see note 9, and Section 4 for further discussion). The question is then, why there would be this limitation. From the existing literature we may infer that memory limitations could play a role.

Sanz and Morgan studied a group of chimpanzees in the wild by closely following them during a couple of months. For our understanding of their memory capacity the following remark is significant: "We also observed that termite-fishing probes may be conserved and transported between nests within a single day." But not, by implication, overnight.

A similar observation comes up in Byrne, Sanz, and Morgan (2013), who discuss a study by Byrne (1998) on tool making by a group of chimpanzees in the Goualougo Triangle (Nouabale-Ndoki National Park, Republic of Congo). Their termite fishing probes are newly manufactured each day, but the chimpanzees have been observed transporting a manufactured probe from one termite nest to another. Their conclusion based on these and similar results, is that the animals are able to use a mental representation of an adequate tool or appropriate natural materials for a task that is not immediately confronting them. But, also in this case there appears to be a limit on the time during which it is active. This suggests an important limitation in their ability to actively maintain internal representations through time.

As in the case of dogs, the performance in memory tasks may vary across domains. For instance, Ban et al. (2014) report on the foraging behaviour of chimpanzees. While foraging they may change travel directions towards high-valued fruit trees they visited at an earlier occasion at further distances, then towards less valued trees. There is a significant effect also when the high-valued tree is still out of sight and as much as 80 min away. As the authors argue such findings are best explained by the possibility that chimpanzees acted upon a retrieved memory of their last feeding experiences, which may be several days earlier, as if they were using memory in an anticipatory manner. Chimpanzees were also observed to depart earlier in the morning if the tree they set out for was farther away (Janmaat et al., 2014). All this suggests a rather developed capacity for planning with goals and sub-goals.

systems also in humans (see Ullman 2004; Beaman, 2010 for relevant discussion). For current purposes it is enough that there would be a limitation on the transfer from working memory to more permanent memory systems (for instance requiring a longer exposure to the stimulus).

Why would there be a difference between the recollection of food sources and the recollection of tools? It may well be the case that – due to color and smell, and relative scarcity – food sources make a stronger imprint on memory than tools, if useable material is easy to come by. Clearly this would need further investigation, for instance by creating situations where tools are hard to come by, as in an experiment with orangutans in captivity (Mulcahy and Call, 2006), which suggests that this may indeed be a factor. (See Vale et al., 2016, for an interesting overview of varying performances in long-term memory, specifically involving procedural memory.) If the difference between food source retrieval and used tool retrieval is only relative, it may tell us that memory resources are a scarce commodity, with no room for 'trivia'.

If such limitations also involve WM, this is consistent with the observation that chimpanzees can use two tools in tandem for a task, and make simple tools, but not truely complex tools.[8] Tool manufacture of this type requires that one is able to access both the current shape and the envisaged shape of the tool under construction. However, it is not the case that access to both representations needs to be available simultaneously. It is sufficient to be able to access the envisaged shape snapshot-wise, that is to have brief 'glimpses' to check whether the tool is being modified into the right direction.

What it takes to make tools is summarized below. The toolmaker must have:

- A mental representation of the goal;
- A mental representation of the shape fitting the goal;
- The ability to find and identify suitable object(s) to start with;
- The ability for a sequential adaptation of objects (branches) to a fitting shape.

Properties of the type of working memory this requires include:

- The ability to maintain a representation of the envisioned shape for as long as it takes to complete the tool.
- The ability to make – at least – "snapshot" comparisons with the envisioned shape and the current shape of the tool as it develops.

Crucially, for truly complex tools one needs more. WM must be able to hold active, not only the element currently under construction, but also the other component that is to be used in the subsequent stage, and do so over a more extended time period. So the type of tool making immediately relates to the memory resources that are available. A limited WM capacity would render complex tool making beyond their abilities. Conversely, a development leading to an enhanced WM would be precisely what is needed to account for the next step in primate evolution: complex tool making. Such an evolutionary step has been argued for in a series of works by Fred Coolidge and Tom Wynn such as their ([Coolidge and Wynn, 2005]2005) article and their (2012) book.

It has to be seen though, whether the step from simple to complex tools is just a matter of 'more of the same' or rather a qualitative difference, and whether for instance a correlation can be established with changes in the genome. We will come back to this in the

[8] There is some interesting discussion of tool complexity in the literature. For instance apes have been observed to use one stone as an anvil and another stone as a hammer. This, however, involves the coordinated use of two simple tools, and need not be considered true complexity. However, in lab conditions they have also been observed to extend a stick by putting another stick in a hole within the former. (See, for instance, Matsuzawa, 1994, and Vale et al., 2016). This is still compatible with an interpretation as using two tools in tandem. It could be seen as a transitional step towards complexity, if one stick would be modified so as to fit better. I have not come accross such observations, though. But even so, it would still be quite far from the complexity seen in early humans as discussed in Section 4.

discussion of tool making in early humans. The issue of quantitative versus qualitative changes also comes up in the role of memory systems in further mental tasks: The mental representation of others in the form of a "Theory of Mind" (ToM).

2.2.2. Theory of mind

Having a theory of mind, that is, forming beliefs of how another person is perceiving us, and that's person possible intentions towards us, is based on the ability to mentally represent others' mental states, and is quite characteristic of human behaviour.

Whether chimpanzees have a theory of mind (Premack and Woodruff 1978) is highly disputed among primatologists. Some (for instance De Waal, 2000) ascribe them quite high level abilities in this respect, others, such as Baron-Cohen (1999), Tomasello et al. (2005), Povinelli and Vonk (2003), are far more skeptical in this regard, and argue that for their apparently stunning feats there are simpler explanations available (see Purzycki (2005) for a lucid overview of the discussion, arguing that the issue will be hard to experimentally resolve).[9]

There are many stories of attempted deception, such as the one in Byrne (1998:117): "A[nother] chimpanzee inhibited its normal tendency to begin eating a coveted food item when it saw the dominant chimpanzee nearby (. . .). The dominant's reaction showed that the deception was not successful: it hid and peeped out from behind a tree. Presumably thinking that the dominant animal had instead left, the subordinate chimpanzee picked up the food, and was promptly relieved of it." Tomasello et al. (2005), however, assert that Chimpanzees can mentally represent what can be seen, but cannot represent (others') beliefs. In any case, there is general agreement on an "upper bound". There is no indication of any behaviour in this domain that goes beyond that of a 4-year old human child.

Interestingly, for a species to develop the ability to mentally represent others' mental states is not just a matter of more of the same. Properties like hair color, size and sex are directly observable. Other's mental states are not. They must be inferred. For instance, the other individual's anger cannot be directly observed. It must be inferred from a facial expression, grunts, a particular posture, etc.

Thus, ToM requires a memory system that is able to *access the result of an inference, as if it were the result of a direct observation.* In other words, if the results from observation can be characterized as 1st order mental objects, inferences are 2nd or higher order mental objects. A simple ToM minimally requires that 2nd order mental objects are treated as equivalent to 1st order mental objects. That is, they may pass the threshold for retention and access. A more complex ToM includes yet higher order mental representations. This immediately links ToM to the idea of *Imagination*: the ability to make images and move them about inside one's head in new arrangements; that is to *manipulate mental representations*.[10] Since the presence of a well developed ToM in humans is beyond dispute, the human memory system must be able to handle higher order mental objects. This step represents an evolutionary *discontinuity*, and is an important characteristic of modernity.[11]

3. Towards modernity

One of the crucial indications of modernity is the use of fire. What does it take to have and control fire? Let's assume that the starting point is some naturally caused fire in the environment. A primate can easily observe that this fire is hot, in contrast to the cold weather and in particular the dwelling cave. Given this, *imagination* comes into play. A new desirable arrangement has to be envisioned as a goal: *a fire in the cave*, causing it to be warm. But note, that even so, this is a non-trivial accomplishment. A mental image must be formed of a non-existing state of affairs that acts as a goal to work towards. This involves manipulation of mental representations of the source situation and the goal situations. So, at this stage already a 2nd order mental representation is involved.

To realize the desired state, first the fire must be envisioned in a form that can be handled: *Burning logs*. To analyze a forest fire in terms of individual burning logs crucially involves the ability to analyze mental representation into sub-parts, and recombine these. Next the *transfer* of burning logs to the cave must be envisioned (taking them out, and recombining them in the place where they will be put to use.) Finally, this transfer must be realized. This is non-trivial, since the burning logs cannot be easily handled. They can be handled by *putting the logs on (or in) some object* that is not hot, and can be transported. Thus, one step will consist of closely approaching the burning logs to manipulate them, crucially requiring *suppression of fear for the fire*.[12]

Thus, a functional analysis shows a pretty complex picture of what must be done in order to get a warm cave; trivial if one assumes a mind that easily moves away from the here-and now, but far from trivial if this moving from the here and now cannot be taken for granted, and is associated with a cost (given limited memory resources). But, it is just within reach, once one has a memory system that can access and recombine 2nd order mental representations.

Summarizing, having controlled fire requires mental systems allowing:

- Maintaining attention through considerable time.
- Handling an object (fire) indirectly – you cannot touch it.
- Handling 2nd order mental representations.
- Keeping active simultaneously two mental representations: the goal, and the object that is being manipulated; just snapshots of the latter will not do.

All of this goes beyond what is needed for chimp style tool making, but approaches what is needed for complex human tools.

To give an impression of the time scale that is possibly involved, according to the literature, the earliest traces of fire use date from a period between 1.500 and 800 ka BP, for instance on the site of Gesher Benot Ya'aqov (790.000 BP), see Wynn and Coolidge (2012: 113, fn 15). For extended time periods one observes no changes in the type of traces found. According to Roebroeks and Villa (2011), there is evidence of controlled fire in Europe as of 400-300 ka BP,

[9] I am very grateful to Simone Pika, currently Research group Pika, Max Planck Institute for Ornithology, for highly fruitful initial discusion of this issue.

[10] There is much more to be said about this issue than I can possibly address here. One intriguing question, raised by an anonymous reviewer, is whether attribution of a believe state necessarily involves a relation between a subject and an abstract propositional representation. If so, the attribution of a ToM to apes would necessarily entail the attribution of having propositional representations, with whatever this entails for linguistic abilities. However, I can very well imagine belief states involving representations in terms of visual images. If so, one could attribute to apes a ToM along these lines, with no implications for linguistic abilities. In any case, as I trust will be come clear in Section 6 ff., in my view propositional thought is definitely not in place before language is there.

[11] Another issue brought up by this reviewer is whether what I say here would not commit me to a position like Paivio's Dual Coding theory (see Paivio, 1991 for an overview). While I can stay neutral as to certain empirical issues that have arisen – and that don't seem decisive – theoretically I am committed to the opposite. As will become clear in Section 6 ff., propositional encoding in the end reduces to the same mode of encoding as other representations; here, instructions for realization (sound or gesture), and structures composed of them.

[12] In fact requiring a form of 'hubris' to overcome it (or *Frevel* according to Freud 1932).

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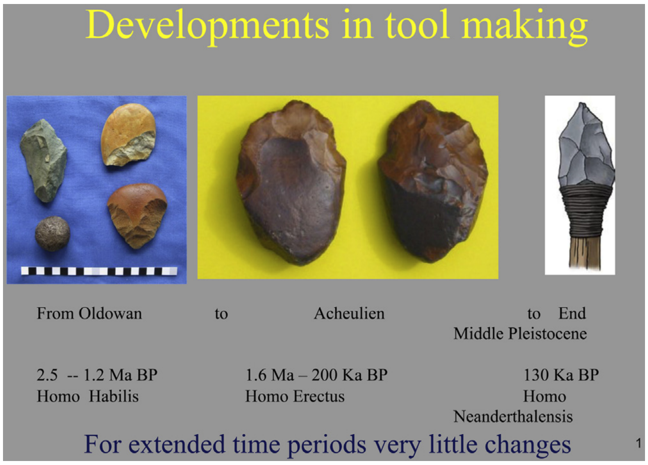

Picture 3. Developments in tool making.

and evidence for clay hearths from 40 Ka BP on (in the period called Aurignacien). It should be noted, though, that nothing in the functional analysis indicates that controlling fire requires language.

4. Tool making

Hominin stone tool making starts in the Oldowan period (2.5–1.2 Ma BP). Stone tools were manufactured by knapping techniques. Stone knapping involves striking stones, especially flint, against each other, causing fractures with sharp fracture lines. Relatively little changed over a very long period of time. It is only at the end of the Middle Pleistocene (130 ka BP) that one finds traces of hafting: attaching a stone head to a wooden stick to produce a spear (or an arrow), see Coolidge and Wynn (2005)'s sketch of Neanderthal hafting on the right. Mazza et al. (2006) report signs of hafting techniques using tar in Italy at the end of the Middle Pleistocene. This development is sketched in Picture 3.

4.1. *A functional analysis of early tool making*

Already this early type of tool making involves quite intricate requirements. The maker must have an eye for material, possible fracture lines, and the right angle for hitting the target stone. (I am indebted to Stan Ambrose for once giving me a highly instructive demonstration.)

In order to understand what the nature of artefacts can tell us about the cognitive abilities of the individual that produced them, a detailed functional analysis of how these artefacts must have been produced is essential. In what follows I will base my discussion on Wadley (2010). Although early tool making definitely involves a much higher degree of eye-hand coordination, and jumping back and forth between mental representation, it can still be seen as an a gradual extension of abilities of (pre)hominin ancestors. There is no clearly fundamental leap from 'being able to use two tools at the same time' (as observed in chimpanzees), to 'being able to strike two stones against each other'. The few changes over long time periods also indicate that developments in early tool making just involve 'a bit better' of the same.

The knapping technique for stone tools requires a cognitive system allowing:

- Maintaining attention through time.
- Manipulating two objects (the knapping stone and the tool being made) simultaneously.
- Keeping active simultaneously two mental representations: the goal, and the tool under construction (including properties of its material).
  - ○ for the knapping stone just snapshots will do (isn't it broken).
- the process is still sequential: after each hit determine if it meets your needs.

A more complex type of tools arises when two objects are combined to one tool with a hafting technique. The question is to what extent the use of hafting reflects a fundamental change in cognitive abilities.

Simple hafting involves representing a goal, and manipulating three objects with their mental representations, the two objects to be combined and the hafting material, including stickiness (as a property of tar). What favors that it represents a leap is that it developed late, after a long stationary period. Functional analysis however doesn't show that it requires fundamentally different mental resources than stone knapping, except for the fact that it involves three rather than two objects. Furthermore, as Wadley (2010) points out, an apprentice could still learn it by watching.

Wadley links her discussion to the more general issue of the role and the significance of recursion in tool making. Although there is a lot of discussion of the notion of recursion in the literature, much of it can be disregarded for present purposes. All that is needed is the basic idea, that a procedure is recursive if it involves *the calling of an instruction while that instruction is being carried out* (see Reuland (2013) for some more discussion in the context of evolution).

Recursion plays a very prominent role in the discussion of the emergence of language, especially since Hauser et al. (2002) argued that it is the core innovation underlying language. The idea is that the availability of recursion in one domain may render it more plausible that it is also available for another domain. But one shouldn't draw conclusions too easily. And, as we will see in Section 7, it is far from enough.

For Wadley (2010) the main question is whether simple hafting involves a recursive procedure in a relevant sense. The question is whether the move from manipulating two objects to manipulating three objects is just a qualitative move – 'two' versus 'three' – or a move of the type 'add one to what you had', what would entail recursion. This seems hard to resolve, but under Wadley's analysis, the next step, *complex hafting*, qualifies for involving a recursive procedure.

4.2. *Complex hafting*

Wadley (2010) presents a functional analysis of complex hafting on the basis of her experiments to replicate complex tools based on the information from the archaeological record. In various places in Africa[13] one finds layers containing tools with traces of ochre[14] and plant gum/resin, with the oldest ones dating from around 70 Ka BP. The significance of this finding can be understood on the basis of the fact that ochre can be used as a loading agent for adhesives.[15] In a nutshell, what we have here is a process in which a compound glue is formed based on plant gum, combined with ochre powder *which has no gluelike attributes.*

As Wadley puts it: "It could not be predicted, without considerable imagination, that the use of items with nonadhesive properties could create successful glue." Also the process involved in making the glue is non-trivial. It involves a chemical reaction that is set in motion by heating. So, we have the following 'equation': *loose, dry powder + sticky, wet gum + heat = hard, dry concreted adhesive*. As Wadley discovered in her experiments, the process only works in

[13] For instance, Rose Cottage Cave – eastern Free State, Sibudu Cave- KwaZulu-Natal, Enkapune Ya Muto – Kenya.
[14] Clay containing hydrated iron oxide.
[15] Historical records indicate that it was still recently used in this way by aborigines in Australia and by the San people from Namaqualand (South Africa).

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a narrow range of temperature: Too low and there is no reaction; too hot and the glue burns. So, a considerable amount of control on the process is needed.

In order to be able to follow this recipe, an individual must have a memory system that is able to maintain an ultimate goal through a range of subgoals. The planning involved requires combining materials in ways not determined by their observable properties. Briefly, what is accomplished requires (i) abstraction from the here and now; (ii) operations on representations of abstract objects (subgoals) in the memory system, and treating these like any other object available for manipulation. Furthermore, Wadley notes that the knowledge involved cannot be obtained by just watching an elder carrying out the task. In her view, transmission of such knowledge involves more than watching: it requires description, and therefore language. Although I will stay non-committed about the last point, especially given what it takes to have language as discussed in Section 7, an individual able to carry out these tasks possesses a cognitive capacity that presumably would look quite familiar to us.

In present terms, complex tool making of this type requires the ability to hold in WM representations that have no direct connection to the sensory system for a considerable time, and to manipulate and combine such representations. The question is whether we can indeed say there is recursion. Clearly, the number of steps to make each tool is finite, as is the number of different tool types involved. Crucial, however, is the availability of subroutines. Thinking about tool making procedurally, once one can haft x to y, there is nothing that precludes hafting x to some y that is itself the product of hafting, coming as close to recursion as one might wish. Even if there are limits in practice on what can be held in WM simultaneously, there are no built-in limits on it in the system.[16]

This reflects an evolutionary leap opening the way for creating images with unbounded degrees of freedom.[17] And, as is important to keep stressing, the presence of recursion is a yes-no property. There cannot be a property of having just a bit of recursion. There can be variation, though, in the domains where recursive procedures are available, and discontinuities where recursive procedures come to be available in a domain where earlier they weren't. We will see this in the discussion of the emergence of language.

5. A big leap: the creativity of imagination

In the Blombos cave we found beads and engraved ochre dating from some100-70 ka BP (see Picture 1). In our own time we have engravings like Escher's *Other world* (see Picture 4). The former is just abstract, the latter an impossible state of affairs. The question is then when we started imagining the impossible. And in fact, we know for sure, that this started more then 30.000 years ago.[18]

Picture 4. Other World by M.C. Escher (1947).

Around 30 ka BP a small ivory figurine was made, the 'Löwenmensch', found in the cave of Hohlenstein-Stadel, and now in the museum of Ulm. It consists of an upper part in the shape of a lion, and a lower part in the shape of a man. A quite impossible being, yet imagined and represented (Picture 5).

We can take Escher's Other World, beads or the engraved ochre from Blombos cave, and the Hohlenstein-Stadel figurine, just like more recent discoveries elsewhere, all as indicative of a fundamental leap. They are all direct consequences of an ability to analyze representations into subparts and freely recombine them.

5.1. Evolution and adaptive value

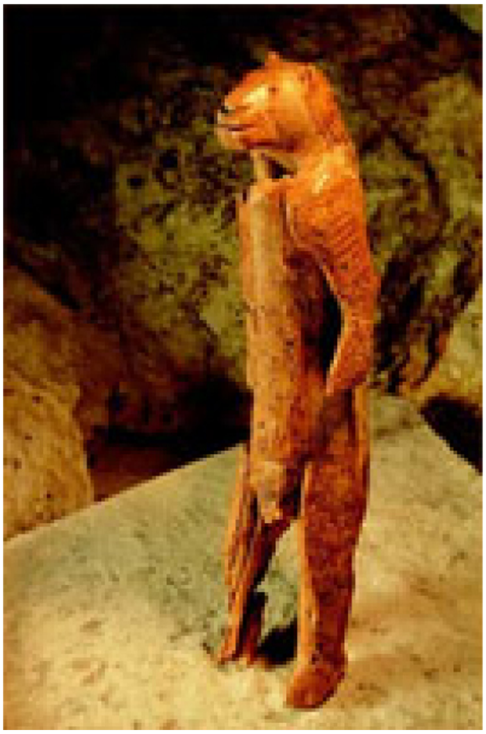
It appears to be an ingrained trait of the human mind to look for purpose. We see this especially in "evolution talk", even by scientists. So, people talk, write, and speculate about the function or the adaptive value of mental time travel, language, etc. In an interview about the possibility of mental time travel in chimpanzees, a researcher states: "I would think that chimpanzees have mental time travel, because evolutionarily it seems so useful to me."[19] (My translation from the Dutch). This, for instance raises the question of why no one would think that my pet crow, duck, or range of cats would have mental time travel. Would it be less useful for them? And if so, why? The psychologist Robin Dunbar (Dunbar, 1996) hypothesized that language evolved as a substitute for physical grooming as an instrument for social bonding as the groups became too large. The question is then, for instance why chinstrap penguins (Pygoscelis antarctica), with subcolonies of op to 1000 nests (Barbosa et al., 1997) did not develop language. It might have been useful for them too. As another example, Falk (2004), hypothe-

[16] One reviewer suggests that hafting could only be reasonably called "recursive" if it is used to create tools whose main use is to create other tools. To my mind it would be quite sufficient if hafting creates an object that can be hafted to an object that it itself the result of hafting. However, as noted by Bob Berwick (personal communication), it is important to emphasize that given the finite number of steps in the manufacture of each tool, in principle finite state processes to describe tool manufacture will suffice. So, it wil be impossible to prove that a more sophisticated process is involved unless we are in the possession of auxiliary knowledge. The question is, what proof can be expected given that we face a general problem in our understanding of the world. As is well-known, it is in principle quite hard to strictly disprove a theory that one is surrounded by – very sophisticated – machines acting like humans. However in practice the more intuitive and reasonable theory that what we think are beings like ourselves are in fact beings like ourselves works out quite satisfactorily. In the same vein, if we see tools that would we would use a recursive planning procedure to produce, and it can be established genetically that their makers are our forebears – hence bear a relevant similarity to us – the most reasonable hypothesis is they have been produced in a similar way as we would produce them. Here, that the makers bear a relevant similarity to us is the auxiliary knowledge one may refer to. But, even so, this is no strict proof. Any conviction can only be based on an act of recognition. Crucially, however, even if we recognize such tools as reflecting a 'human' procedure, still no conclusion is warranted about their makers having language.

[17] See Shipton et al. (2013) for more discussion of recursion in tool making.

[18] The literature puts the earliest traces of 'symbolic behaviour' at around 130 ka BP. The earliest examples of figurative artefacts – including impossible objects – only come up at around 32 ka BP, although not limited to Europe, as often thought. See d'Errico and Henshilwood (2011) for discussion.

[19] Quote from Karline Janmaat (Max Planck Institute for Evolutionary Anthropology, Department of Primatology) in *Morgen ga ik vijgen eten* ('Tomorrow I 'm going to eat figs', my translation) the NRC Weekend, November 8 & 9, 2014



Picture 5. Löwenmensch from Hohlenstein-Stadel, Europe, 30 ka BP.

sizes that language evolved due to the need for "maternal silencing, reassuring, and controlling of the behaviors of physically removed infants". Who knows? Sea-turtles are also physically quite removed from their infants, and I also never saw a duck being able to hold her ducklings close (surprisingly differing from grebes). Yet none of these species developed anything like language as we know it.

Looking for purpose and 'adaptive value' in evolutionary processes is commonplace, and tempting.[20] Yet a moment's reflection should be enough to make us wary of this concept.

From the primordial soup a rich diversity of organisms evolved, varying from squids, E-Coli, jacaranda trees, lichens, sloths, ants, bonobo's, cats, corn, and us. Apparently, they all were fit enough to survive until this very day. Of course, the crucial notion is that of «niche». *Fit* is determined with respect to a niche, a particular environment, and not with respect to the earth as a whole. However, as pointed out by Fodor and Piattelli-Palmarini (2010), the problem is that we have no predictive theory of natural selection. And, even if the situation is a bit less bleak than Fodor and Piatelli-Palmarini suggest, we certainly don't have one that can be successfully applied in the case of human evolution with regard to language.[21] Proposals like those of Dunbar and Falk are at best post-hoc. But if one casts the net a bit wider it is easy to see that looking for purpose or adaptive value in human evolution is profoundly problematic. It is hard to see anyone investigating and answering the question of what is the evolutionary advantage of a further range of traits humans have. Why for instance are there enough humans who enjoy watching mime for mime playing companies to make a living, basic as it may be?[22] What is the evolutionary advantage of being able to appreciate pictures by Hieronymus Bosch, Van Gogh, Dali, Mondriaan or Escher? Why is Jeff Koons able to make a living? Why did we develop music, from Hildegard von Bingen, or J.C. Bach, to the atonal music by Stockhausen, or the aleatory music by John Cage? Or from Prince to the Eagles of Death Metal.

In all these cases the simplest and best answer is that there is none, and that it is the wrong way to approach the question. None of these traits are any provable good from an evolutionary perspective. The more promising answer to why we have them is the same as the answer attributed to George Mallory as to why he wanted to climb the Everest: Because it is there! With Chomsky (for instance, Chomsky, 1986) and Gould it seems worth to seriously explore the possibility that language is 'just' an evolutionary by-product, a spandrel (see Gould and Lewontin, 1979).

It cannot be sufficiently stressed that given the type of combinatorics implied by tool making there is no principled difference between 'useful' and 'useless' creations (tools versus beads or figurines). Having the one, entails having the other. Combinatory principles applying to simple representations to imagine complex tools, will equally well apply to objects, lines, shapes, colors, or tones, to yield other complex representations. The reason we have art is that once you have the freedom to make tools, anything becomes possible. And, if we cannot say good-bye to 'use'- and 'purpose'-talk, we better accept that what is useless at first may subsequently find a use. The driving force behind this need be nothing more than "play", not deeper than what one sees in kittens, bears or foals in a meadow: exploring their potential.

5.2. *Combining away*

Thus, it is of no use to ask what the various results of recursively applying combinatory principles are good for from an evolutionary perspective. Once you are able to combine elements, you get the rest for free. A combinatory system doesn't stop half-way.

In order to see this, consider the number system. Peano's axioms define the set of *natural numbers* and their properties as follows:

1. 0 is a natural number
2. For every natural number x, $x = x$ (reflexivity)
3. For all natural numbers x and y, if $x = y$, then $y = x$. (symmetry)
4. For all natural numbers x, y and z, if $x = y$ and $y = z$, then $x = z$. (transitivity)
5. For all a and b, if a is a natural number and $a = b$, then b is also a natural number. (Closure under equality).
6. For every natural number n, $S(n)$ is a natural number. (Closure under the successor function).

Under these axioms the natural numbers are all 'given', irrespective of their notation, or their size. A natural number that requires only 3 digits to write down in a decimal notation is no more given than a natural number that would require a trillion digits to write down. One cannot discover new natural numbers, although one could in principle identify particular expressions as representing a natural number that has never been represented before (or not in that particular manner). And, of course, even if they are all given, as are their properties, this doesn't entail that all their properties have been identified (as anyone interested in mathematics is well aware of).

Clearly, any physical system will pose restrictions on the representability of the output. So, assuming an attempt to enumerate all the natural numbers, for the application of the successor function it is irrelevant whether it is applied for the 1st time or for the 10^{80th}; but after 10^{80}, which Wikipedia estimates to be the number of elementary particles in the universe, you may run into a problem representing the result. Does this mean that we have to build this limitation into our math? (Like some claim it has to be done for

[20] The list from Pinker and Bloom (1990), to Christiansen and Chater (2008) up to the present day is quite endless.

[21] See already Wallace (1871), as pointed out in Berwick and Chomsky (2016), who also explicitly draw attention to Eric Lenneberg's work, such as Lenneberg (1967), which provides an early example of fruitful thinking about the evolution of language.

[22] This question came up while watching a performance by the mime company Schweigman&. While I was tremendously enjoying myself, I could not keep myself from wondering why.

language?) That would be the wrong way to go. First of all, this number of 10^{80} may turn out to be off the mark, and second, who says one would have to represent the numbers physically? The system would simply allow you to go on after exhausting, or even without exhausting, the physical universe, just using the time dimension.

5.3. *Novelty and indeterminacy*

This result has interesting implications for our understanding of novelty and indeterminacy, for instance in the relation between poetry and 'new meanings'. There is something unexpected, and novel about good poetry. But can it be the creation of new meanings? If we apply the logic of recursive combinability to this idea it cannot be like that (as we might already know from Fodor (1983) and much subsequent discussion).

A combinatory system of concepts creates a full space of meanings once and for all. However what poetry does is allow us to search through this space and find and identify meanings that so far have not been identified or expressed before.[23]

Combinability creates a contained, but bound-less space of options, in which every coordinate is attainable, but only a dwindlingly small fragment can be actually attained. This has also implications for the tension between accountability and determinism often raised in the philosophy of ethics, which can thus be resolved: Just like the set of true mathematical expressions cannot be formally characterized (Gödel's incompleteness result), the set of 'personally justifiable' courses of action is fundamentally non-determinable from a given individual's initial state of mind.

Let's summarize the minimal requirements on mental representations needed for each leap towards 'modernity':

- Hafting: combining on the basis of derived properties;
- Strings of beads: a combination of objects created on the basis of abstract qualities;
- Löwenmensch: combining elements into a representation of a non-existing object.

Commonality: A mental system that can hold complex representations formed by (free) combination and accesses properties beyond the initial appearance of an object.

5.4. *First order imagination*

Where do we stand? Does a mental system with the characteristics discussed so far go all the way towards modernity, or does it constitute just an intermediate step?

Given the availability of operations on representations one should note that what such operations can achieve depends on the elements in the analysis of representations:

- Distinguishing parts entails the possibility to play with recombination of such parts.
- Distinguishing borders between parts entails the possibility to recognize lines, which entails the ability to play with shapes, ultimately leading to drawing.
- Identifying surfaces between borders leads to the notion of colors, which in turn facilitates playing with colors, and ultimately leads to painting.

Assuming that an analysis of representations into lines and colors reflects an older and independent evolutionary event, an increase in working memory capacity will make it possible to hold

Picture 6. Three examples of 1st order imagination.

and access complex representations formed by free (re-) combination of component parts. This reflects what one may call *1st order imagination*. Given such a system the prerequisites are met to imagine paintings, from the famous bison in the Altamira cave +/−15000 BP on the to Escher's *Other world* from the first half of the previous century. Or from Hieronymus Bosch's *Hell* (the right panel of "The Garden of Earthly Delights", from the last decade of the 16th century), to one of Salvador Dali's paintings of an egg, realized in an uncannily similar style almost 500 years later, all illustrated in the next picture (from upper left to lower right) (Picture 6).

A mental system with only 1st order imagination is nevertheless still limited. There is quite a bit it cannot do! A system restricted to representations derivative of objects cannot represent abstract concepts, impossible notions, quantification, modality, or states of affairs relative to some coordinate system, as, for instance, in (1):

(1)

a A square circle
b That every hunter who saw it hit some bear that chased him.
c That the chief's father told him yesterday that tomorrow's hunt will probably be much better than his last hunt the year before.
d That the priest will probably like to have her first food at sunrise tomorrow morning.

In order to achieve the necessary departure from the here and now we need the next step: *Language*.

6. Language: some initial issues

As already indicated in Section 5, there is a lot of discussion about the evolutionary origins of language and why it evolved, with proposals based on notions such as adaptation and evolutionary advantage that look plausible, but are just post-hoc.

Let's start with a definition of the core notion *Language*. As a first approximation we can say:

(2) Language: first approximation

A language is a systematic mapping of forms in some medium (sounds, gestures) and interpretations (instructions to change/update internal representations).

In this form the definition is very broad, and covers much that we would not want to call language, at least not human language. A second approximation is given in (3):

(3) Language: second approximation

[23] Thanks to a meeting with the poets Mark Strand and Mustafa Stitou for enabling me to express this more clearly than I could before.

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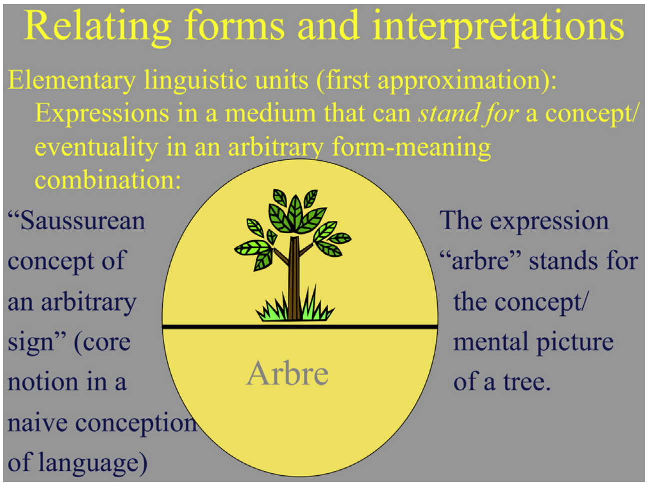

Picture 7. The Saussurean Sign.

A language is a systematic mapping of forms in some medium (sounds, gestures) and interpretations (instructions to change/update internal representations), based on a finite initial set of arbitrary form-meaning combinations

This approximation takes the definition of a *sign* from Saussure (1916), as a starting point as sketched in Picture 7.

This simple concept of a sign is as far as most discussions by non-linguists in the vast literature on the evolution of language go. However, as is easy to see, this approximation is still far off the mark. Language contains a vast inventory of *function words*: articles such as *the*, *a*, prepositions like *on* in *John counted on his good luck*, complementizers such as *that* in *I hate that I have to stop now*. These don't denote concepts the way *arbre* does. They do make a contribution to interpretation, though, but in a different way, as will be discussed in Section 7. For the moment we may abstract away fom this issue, and continue to base our discussion on this notion of a sign. Clearly for us to have anything like language at all, such signs must be combined and their combinations must be interpreted.

6.1. An evolutionary fable

A helpful starting point for further discussion is provided by the following 'Evolutionary fable' from Chomsky (2000), given in (4):

(4) *Given a primate with the human mental architecture and sensorimotor apparatus in place, but not yet a language organ. What specifications does some language organ FL have to meet if upon insertion it is to work properly?*

For an understanding of the evolution of language we must, then: (i) Develop a *functional analysis*[24] of what is required for language as we know it (see Reuland, 2010); (ii) Determine in what respects the mental resources needed for language go beyond what is needed for complex tools (but parsimoniously, since nature makes leaps, but not very big ones). In order to achieve our further goals we have to (iii) Determine how language bears on imagination.

Elaborating on Chomsky's fable, having language entails having:

(i) A *thought* system (not specific to language), with an articulation (of the internal representation) of the world into *concepts* (spear, fire, bear, hunt, haft, kill, warm, on, . . .), and *events* (with a temporal structure and participants), so as to allow distinguishing the various components in (*The*) *hunter* (*will*) *haft* (*the*) *head* (*onto the*) *spear*, but *no combinatorics*.

(ii) A *realization* system (not specific to language): Articulation of events in an external medium into discrete repeatable units: sounds, gestures, . . .

(iii) A *computational* system (possibly in part specific to language) relating the two. It is the latter that should give the primate language once inserted.

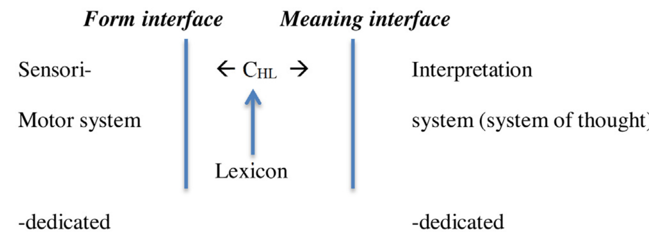

Fig. 1. Language as a systematic mapping of forms onto interpretations.

This leads us quite straightforwardly to the schema of the language system in Fig. 1 above (from Chomsky, 1995). Together with the notion of a sign this will serve as a basis for further discussion, since it enables one to formulate the relevant issues sharply, and is so general that it should not be controversial.

As schematically indicated in Fig. 1, the *Computational system of human language* (abbreviated as C_{HL}) is the system that determines the way in which the minimal units of the grammatical system can be combined. To use the more traditional term, it is just 'syntax'. It is this computational system that, mediated by the lexicon, connects the Realization system (the system of Forms) with the Interpretation system, via the two interfaces (note that neither the realization system, nor the interpretation system are dedicated/specific to language – the former is also used in many other activities from eating to crying, etc., the latter for conceptualizing). The elementary form-meaning mappings are represented in the Lexicon.[25] This does not imply anything about the size of these minimal combinations. These may vary from elements such as *–ed* standing for PAST when combined with a verb, articles such as *the* conveying definiteness, to composite verbs such as *transform*, or to large units such as *kick the bucket* standing for DIE. In fact, without change in principle, elements could include templates/constructions in the sense of 'construction grammar' (Croft, 2001).

For an understanding of the emergence of language, the core question is: *What are the innovations leading to language*? Taking into account that language involves a coupling of forms and interpretations, instead of materials and a goal, we can ask in what respects the system underlying language goes beyond what is needed for complex tools.

With complex tools we have a combinatory system, and a WM able to maintain mental representations of the current state and a goal (the envisioned state) through time and an ability to monitor progress. That is, we have *pairings of mental representations*. We can also look at language from this perspective. The sounds and gestures realizing language are part of the external world, just as the materials for tools, but their representations as *instructions to the*

[24] Though definitely not a *functionalist* anaysis.

[25] For the purpose of this contribution I will stay away from current issues about the relation between form and interpretation as they are discussed in frameworks such as Distributed Morphology (Halle and Marantz (1993), and subsequent work) and Nano-syntax (Starke 2011; and others). See Berwick and Chomsky (2016) for a more fundamental discussion of the asymmetry between the form and the interpretation components of the language system. Crucial is that the form component is sufficiently transparent to provide a window on the interpretive system (see Reuland, in press, for more discussion).

motor system for realizing them[26] are part of the world's internal representation in the mind. Turning to the simple case of a sign, what we need is that one mental representation – the (instruction to) form 'arbre' – can *stand for* another mental representation, namely the concept TREE, and that the latter is handled by handling the former. Thus, *mental representations of instructions to the motor system* for producing sounds or gestures can stand for *concepts*; again we have *pairings of mental representations.*

The notion of *standing for* need not go much beyond what is needed for tool making. The mental representation used as a reference point in monitoring progress can be said to stand for a goal. But this reference point is still connected to something concrete, for instance a tool as it has been used earlier. One can still think of this earlier tool as acting as a reinforcement to keep the goal representation active.

If so, one core innovation for language may well be what enables using the *stand for* relation for *arbitrary pairs*, that is, the ability to *operate on one member of a pair as if it involves an operation on the other member.* Whereas the concept still has some external motivation, the instruction to realize has only internal motivation. Working with the latter requires the ability to keep representations active without outside reinforcement. In a nutshell as in (5):

(5) *Internally produced stimuli are treated on the same footing as externally produced stimuli, making them as effective in keeping the representation active.*

Although such an innovation can be understood as an extension of what was already there, it goes just a bit beyond being 'more of the same'. It does reflect a discontinuity, small as it may seem.

6.2. Recursion and the motor system

Thus, Saussurean signs/lexical items, the way we discussed them, are Janus-like elements. One face belongs to the domain of instructions for the motor-system, the other to the domain of concepts/interpretations. The suggestion in Hauser et al. (2002), that recursion is the core innovation in the evolution of human language sparked a discussion of whether recursion is indeed unique to language, or even unique to humans. In fact, Hauser et al. themselves already suggested that recursion in language has been 'borrowed' from the motor system. And indeed, if so, this makes for a quite parsimonious story. It is uncontroversial that our system for the planning of loco-motion allows for sets of instructions that can be combined in sequences, and embeddings with goals and sub-goals, ad infinitum. However, we also know, as we saw, that apes have concepts, but cannot freely combine them (Terrace et al., 1979). Apes also have a highly developed, intricate motor system for locomotion and other activities, coupled with planning, as we saw in Section 2.2.1. That is, recursion, but not in the relevant domain. This means that something more must be involved in language than just having concepts and a motor system. The simplest twist is then that one key innovation for language is that the conceptual-intentional system 'takes a ride on the motor-system', but not in a trivial sense: They must be able to talk to each other as in (6)[27]:

(6) *Finding its grip on the form-side of lexical items as instructions for (delayable) realization, the motor system combines and recombines them, yielding complex expressions that serve as input to the interpretation system.*

If so, this is consistent with the observation made in the context of Baddely's model (Picture 2) that a successful rehearsal strategy is form-based rather than content based.

This leads to the following minimal requirements on a (working memory) system for language:

i. The ability to hold representations of abstract properties:
   - satisfied by Blombos beads
ii. The ability to hold representations of two or more objects simultanuously.
   - satisfied by the manufacture of complex tools.
iii. The ability to use and access internally produced representations on the same footing as representations produced in response to external stimuli (keeping internally produced representations sufficiently active).
   - A requirement for effective imagination, and a potential discontinuity.
iv. The ability to treat one representation (a "form", reflecting an instruction to the motor system for realization) as *standing for* another representation (reflecting "content"), let's call this '*coupling*'.
   - functionally an innovation, but possibly reducible to the previous one; if new quite marginal in view of raisin + ochre + heat = glue
v. The ability to let an operation on form feed another operation on form.

In a nutshell:

> Forms can be handled as proxies for content. Using key features of the motor-system, this leads to recursive combinability of linguistic forms.

In very general terms this comes down to *lifting a restriction* or *crossing a barrier.*

It is this type of discontinuities that one should pay attention to in understanding the evolutionary path towards language.

Much of the current discussion in linguistic theory centers on the question how rich this combinatory syntactic system is. Let's now summarize some of the key features.

6.3. The computational system

A leading hypothesis in Chomsky (1995) and subsequent work is that the computational system has only a very limited nuber of operations. It just consists of the operations *Combine* (technically, *Merge*) and *Compare* (that is, the ability to check the contents of some elements and determine whether they are the same in some relevant dimension, technically *Check*), followed by property sharing (*Agree*) if there are properties (features) to be shared. The result is a hierarchical structure.

A further important issue is to what extent the systems underlying language are specific to language, or whether language is just the result of operations that are generally available within the cog-

[26] Instructions to the 'printer', to use Berwick and Chomsky (2016)'s terms.

[27] Berwick and Chomsky (2016) express skepticism about standard versions of the emergence of language as parasitic on the motor or planning systems. Also Moro (2013) argues that one should be cautious reducing syntax to a planning system, if only because syntax does not only consist of a lexicon and Merge, but also crucially includes locality conditions limiting the number of successful combinations yielded by Merge. I agree. What is required is for the two systems to be able to talk to each other. This requires a rewiring that, though simple, is non-trivial. Such a crossing to another modality may well introduce the loality effects Moro points out (note that the current interpretation in terms of phase theory, as in Chomsky (2001, 2008), may ultimately be related to working memory limitations). In fact, as far as I can see the idea of language requiring a crossing – a connection – between components of the cognitive system as sketched in the main text seems quite compatible with Berwick and Chomsky's discussion of the anatomical picture in Fig. 4.4. Crucial for language is that a 'ring' involving dorsal and ventral pathways be closed, where one of the dorsal pathways involves the motor-system, and the ventral pathways connect the region where the lexicon is taken to be to the front dorsal region. As they note, it is quite suggestive that at birth, when syntactic processing is not yet available, the ring is not yet closed.

nitive system, applying to linguistic units. In the form sketched so far, what is required doesn't seem to go beyond what is needed for tool making. But for more dependable answers one should look in detail at precise enough characterizations of the linguistic operations and the restrictions they exhibit. Indeed, the operation Merge in its simplest form can be easily seen as a domain general operation. It is hard to see why the notion of combining would be specific to language. However, as it turns out, what is needed for language is an operation that is just a bit more complex: if two elements are combined, also something has to be said about the nature of the result. For instance, if one combines the verb form *saw* and the proper name *Jill*, yielding *saw Jill*, as in *Jack saw Jill*, the result is verbal rather than nominal. If one combines the preposition *behind* with the proper name *Jack*, yielding *behind Jack* as in *Jill was sitting behind Jack*, the result is again not nominal, but this time prepositional.

Thus, generally, when merging *a* and *b* it should be determined which of the two determines the nature of the combination, i.e. which of the two is the *head*, using a symbolic notation, $a + b \rightarrow <a,<a,b>>$ *OR* $<b,<a,b>>$. Thus, it is non-trivial to reduce the actual operation Merge to general cognitive principles. In fact, what doing so requires is deconstructing the operation Merge into two independent operations, Combine and Determine Head, and find an independent rationale for both. For Combine in its simplest form this is straightforward, for Determine Head this is perhaps less so, but in informal terms it comes down to making a distinction between goals and subgoals and the ability to maintain a main goal in mind while working within a subgoal. Just like preparing hafting material takes place keeping the goal in mind that it is to be used for hafting x to y, combining a preposition and a proper name takes place with the goal in mind to use the result as a modifier. That is, the result should be a type of preposition, rather than a type of nominal. What is crucial in language is that in this case the goal-subgoal distinction is entirely internally motivated. In this sense, then, what is novel in determining the head reduces to the innovation we already established before.

One option is for Merge to retrieve some element from a mental store, and combine it with an element, possibly complex, which is already in the mental workspace. For instance, retrieving *Jack* and combining it with *saw Jill*. But, given the basic concept of combining, nothing stands in the way of accessing a piece that is already part of the structure, and recombining (remerging) it with what already is there. For instance, accessing *see Jill* in *Jack will see Jill*, and attaching it up from, yielding *see Jill, Jack will*, or even simpler, just accessing *Jill* and forming *Jill, Jack will see*. That is, language has the property of dislocation, but this as such is not an innovation. As Chomsky (1995) stresses, *having Merge* entails *having dislocation*, unless one would exclude it by stipulation.[28] (For a tentative discussion of *locality conditions* and working memory see Reuland, 2010).

However, as pointed out in Reinhart (2006) having a computational system of this sort is by far not sufficient for language. For language to be possible another barrier has to be crossed, the barrier between the computational system and the concepts system.

6.4. Accessing the concepts system

Pursuing Chomsky's evolutionary fable, Reinhart (2006) gives a lucid exposition of the issue, which deserves being quoted extensively:

> "Imagine a primate that by some mystery of genetic development acquired the full set of the human cognitive abilities, except the language faculty (FL). We can assume, then, that among other cognitive abilities, he has a system of concepts similar to that of humans, and a sensorimotor system that enables perceiving and coding of information in sounds. Let us assume, further, that he has an innate system of Logic, an abstract formal system, which contains an inventory of abstract symbols, connectives functions and definitions, necessary for inference. What would he be able to do with these systems? – Not much. . . .. the inference system operates on propositions, not on concepts, so it is unusable for the primate in our thought experiment. *Possibly, he can code concepts in sounds, but not the propositions needed for inference* [my italics, EJR]. Pursuing this thought experiment, the goal of linguistics theory can be described as reconstructing the system that the primate lacks, which consists of whatever is needed to enable the interface of his various cognitive systems. Namely construct the computational system – CS – (syntax in a broad sense) that defines L(anguage), (a state of the FL organ – Faculty of Language), which enables this interface."

The question is then how whatever is formed by the combinatory system (syntax) may serve as an input to the interpretation system. Recursively combining forms is of no use unless its results can be read by the interpretation system and interpreted. To put it in Reinhart's terms, properties of the concepts system have to be *legible* to the syntactic system and vice versa. Let's refer to this as the legibility requirement:

(7) *Legibility requirement*

Properties of the concepts system must be legible to the syntactic system (and vice versa).

Reinhart (2002, 2016) develops a specific proposal about legibility in the domain of verbal concepts. Her crucial insight is that syntax can access the system of verbal concepts only through a narrow channel. What is visible to the syntactic computational system are those properties that can be encoded with two binary features reflecting 'perceived causation' and 'mental involvement', in short [±c, ±m]. Whether or not an eventuality denoted by a predicate is cruel, entertaining, important, boring, etc., may be highly relevant to participants involved in the speech event, but irrelevant for syntax. What is important for syntax is whether the verbal concept takes arguments that bear the roles of agent ([+c+m]), theme ([−c−m]), experiencer ([−c+m]), etc. So, for instance, in a sentence like *John killed the deer*, *the deer* is neither mentally involved, nor perceived as a causer, hence a theme; *John* on the other hand is both mentally involved and a perceive causer, hence an agent. In *the wind opened the door*, *the door* is again a theme, but *the wind* is perceived as a causer, but is not mentally involved, hence its role is instrument, rather than agent.

I now will discuss another instance of the legibility issue, bringing a number of crucial properties of language into play. In the end we will see whether they can somehow be unified, and lead us to an overall characterization, in fact suggesting one key innovation.

7. Language: structure building unleashed cum legibility

Given an innovation in the organization of WM, allowing *coupling*, let's consider its effect on the capacity for language in more detail.

As discussed, a core property of language is that its elements can be recursively combined into larger units that can be combined in turn into yet larger units. Informally: *Combine* may apply to its own output. Recursion unleashes combinability into its full potential (Hauser et al., 2002) (see Coolidge et al., 2011 for further instructive discussion). But, as noted, combinability by itself does not give us much. Birdsong too can consist of essentially unlimited

[28] See Berwick and Chomsky (2016) for more detailed discussion in an evolutionary context.

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combination of motifs. To have anything like language in our sense, a next step is necessary. The combination rules must be associated with interpretation rules that act on the resulting configuration. These in turn require mutual legibility. To see what may be involved consider the minimal linguistic units and their relations in more detail.

7.1. Interpreting the result of structure building

As already briefly mentioned in Section 6, the presence of function words shows that not all minimal language forms fit the conception of a Saussurean sign. It is relatively straightforward to think of an underlying concept for adjectives such as *brown*, or nouns such as *bear*, as representing properties of individuals. Verbs such as *hunt* or *open* represent relations between individuals. However, there is a whole range of lexical elements that don't stand for concepts in this sense.[29] Consider for instance the element *the* in English. It is easy to see that there is no concept 'the-ness', comparable to 'brown-ness', or 'bear-hood'. Or consider the modal auxiliary *will*. Clearly there is no event type associated with *will* like there is with *open* or *hunt*. Elements, like *will*, *the*, *a*, but also *every*, *some*, etc., are function words. They reflect what appears to be a further core property of human language: *desymbolization*: *signs may be stripped from conceptual content*. We also see desymbolization in other categories. Whereas a preposition like *on* in *John was standing on the rock* can be argued to stand for a spatial relation, no such interpretation is available for *on* in *John depended on his luck.* But clearly, such function words do make a significant contribution to interpretation: they constitute *instructions for interpretation*.

In order to see how this may work, we first have to address the relation between the conceptual system and the syntactic system more generally. Suppose we have two signs/concepts, *brown* and *bear*. Suppose, furthermore, that they have been combined, into *brown bear*, how does the interpretation system arrive at the interpretation of *brown bear* on the basis of the meanings of *brown* and *bear*? The minimal assumption we need, it seems, is that both represent properties. Properties, intuitively speaking, have an *opening* for an individual as the bearer of that property by virtue of what they mean. Or, to put it differently, the concepts *bear* and *brown* reflect properties that may apply to an individual.

The fact that they may potentially apply to *any individual*, indicates that from a semantic perspective these openings reflect *variables*. This can be represented in standard logical notation with a so-called lambda-operator as $\lambda x.\ brown\,(x)$ and $\lambda y.\ bear\,(y)$ respectively, where the λ-operator is just a formal way of conveying that the following expression (e.g. *brown (x)*) can receive an argument valuing the x.[30] *Brown* and *bear* thus act as *restrictions* on these variables x. Semantically, the interpretation of *brown bear* can be given as for instance $\lambda x.\ ([brown\ \&\ bear]\ (x))$, or as $\lambda x.\ (brown\ (x)\ \&\ bear\ (x))$. This is what we informally may refer to as 'modification'. Thus, modification can be represented as set intersection, with the shared variable acting as a linking pin. Note that modification doesn't care about sense, nonsense, probability, etc. It interprets *ugly bear*, as easily as *square bear*, *square circle*, *uncanny improbability*, *black hole*, *white hole*, etc., while giving a slightly different twist to *former chief*, *alleged murderer*, and their like (see below). It is important to see that there is nothing 'natural' or 'self-evident' to this interpretation rule (unlike what I occasionally found to be taken for granted by some non-linguist colleagues). Other combinations require a different rule. The interpretation of a combination like *the bear* or *a bear* is certainly nothing like $^*\lambda x.\ (the\ (x)\ \&\ bear\ (x))$ or $^*\lambda x.\ (a\ (x)\ \&\ bear\ (x))$. Or in *John hinted at the bear* the interpretation of *at the bear* is again nothing like $^*\lambda x.(at\ (x)\ \&\ bear\ (x)$. In the case of *the bear*, its interpretation, based on the instruction for interpretation associated with *the*, is given by 'value the expression *the bear* with the unique individual in the context of utterance who is a bear'.[31]

The fact that we need diferent interpretation rules for different combinations may seem trivial, but it is ignored in all discussions of evolution of language I am aware of.

What I said so far about openings and variables is not enough to understand how combinations of elements like *brown* or *bear* are to be interpreted. In order to have interpretation rules (such as, for instance, modification), it is crucial that openings/variables are legible to the grammatical system. This relates the present discussion to the more general legibility issue raised in (7). That is, what makes properties of concepts – by nature non-linguistic as they are – legible for the computational system?

7.2. Introducing variables

Developing a comprehensive account of legibility extending Reinhart's approach to the whole range of linguistic categories would be a fully-fledged separate project. What is important for now is the need for a syntactic channel for such variables as linking pins. Thus, there must be a syntactic counterpart to the opening in concepts such that i. it is legible to the computational system, and ii. its occurrences can be identified providing the means to establish relations between concepts. What we need, then, is a *syntactic* notion of a variable (which may or may not end up having a close counterpart in the semantics). It is through identification of syntactic variables that *brown* and *bear* enter into a modification relation in *brown bear*. It is by the identification of syntactic variables that the semantic relations in (8) can be made explicit.

(8)

a A brown bear grunted
b $\exists x\ (\exists e\ (bear\ (x)\ \&\ brown\ (x)\ \&\ Agent\ (e, x))\ \&\ grunt\ (e))$

(Where ∃ stands for the existential quantifiere 'there is', x stands for a variable over individuals, and e stands for a variable ranging over events, yielding, informally, that there is an x such that x is both brown and a bear and that x bears the agent role in a grunting event.)

I would like to venture that the use of legible variables in one form or other is a crucial prerequisite for being able to establish a

[29] What underlies the emergence of such concepts, one could argue, is the ability to generalize over exemplars and/or prototypes. This touches on an ongoing discussion in the field of concepts learning that it would be far too ambitious to even try to do justice, see for instance Nosofsky (1986), and Nosofsky (2012).

[30] Formally, λx. (Px) denotes a function from individuals to propositions. Unlike the openings in the concepts, we need not assume that the λ-operator belongs to language as it is mentally represented (which is the object of investigation). It is rather part of our theoretical means to describe the properties of the object language. Similarly, it is important to distinguish between al least three notions of a variable. There is an intuitive sense in which the openings in concepts are variables. As such they are part of the object language. Similarly, as we will see, pronouns, in one of their uses are also properly analyzed as variables. However, linguistic theories may differ in the way in which they represent the notion of a variable. As an anonymous reviewer rightly points out, some theories may contain a grammatical level of representation involving variables in the logical sense, but there is also an alternative formulation (e.g., as in Jacobson, 1999) that eliminates variables but includes another mode of meaning composition. A full discussion of the issue would carry us far beyond the scope of this contribution. However, it is important to realize that although for instance pronominals are not rendered as variables in Jacobson's system, their variable meaning is clearly represented in the interpretation they receive as the identity fuction.

[31] For short in logical notation $\iota x.bear\ (x)$. This notation uses a technical device, the iota operator, but means the same as I formulated in words. Thus, the way in which the determiner *the* applies to *bear (x)* is made explicit by the iota operator *binding* the variable.

relation between composite forms and their interpretations. Without such variables, then, no language as we know it is possible:

(9) Key innovation in the emergence of language: *The emergence of legible variables.*

It is the emergence of legible variables that enables a crucial and unique property of human language: *Expressions may depend on another expression for their interpretation*, as will be discussed in more detail in the next section, where variables play a key role. Although I will keep the discussion as informal as possible, a minimal degree of technicality cannot be avoided.

7.3. Towards legibility: pronouns and variables

In all languages certain expressions can stand for (mental representations of) individuals (for sake of brevity I will henceforth omit 'mental representations of'). So, it is possible for *The warrior* and *the man* to have the same discourse individual, let's say *j*, as their value, as in (10). That is, they *may corefer*.

j

(10) The warrior has a spear. Will the man attack?

But, languages also have pronominals such as *he*, *she*, etc, which lack lexical content, i.e. are not associated with a concept. So, there is no concept he-hood comparable to man-hood or priest-hood: it is a function word. However, just like expressions like *the man*, *he* can receive a discourse individual as its value, allowing the two to corefer, as in (11):

j

(11) The warrior has a spear. Will he attack?

Consider next (12) where the referential expression in the first clause has been replaced by another type of expression, namely a quantificational expression:

(12) No warrior has a spear. *Will he attack?

As a discourse, this is not felicitous. Intuitively, the explanation is straightforward (see Heim, 1982): *No warrior* does not refer to a discourse individual. Hence, there is no individual it can share with *he*. But this raises a question about the sentence in (13):

(13) No warrior who has a spear doubts that he will attack.

This sentence is fine with an interpretation where *he* depends for its interpretation on *no warrior*. As we saw, coreference is impossible. The fact that (13) is well-formed illustrates a different dependendency relation, namely *binding*. In a nutshell, binding makes it possible for *he* to depend for its interpretation on another expression, instead of a discourse individual. This is informally illustrated in (14), where *he* depends on *no warrior who has a spear*. That is, the interpretation of *he* proceeds indirectly, via its antecedent, rather than via a direct link to the discourse. More formally this is represented in (15).

(14)

[$_S$ No warrior who has a spear (x) [$_{Pred}$ doubts that he will attack]].

(15) No warrior who has a spear [$_S$ (λx. (**x** [$_{Pred}$ doubts that x will attack]))]

Some of the internal structure is indicated with informal labels for S(entence) and Pred(icate). Like all expressions such as *bear* or *man* the complex expression *no warrior who has a spear* contains a variable that is restricted, indicated by the variable *x* in (14). The way (15) relates to (14) can be expressed by translating the pronoun *he* by a variable, and moving the restriction of the subject *no warrior who has a spear* out of its original position, leaving the variable it restricted behind (the one in bold face) and identifying the latter with the variable translating *he*, leading to two occurrences of *x*.

The dependency in sentences such as (13) represents an evolutionary innovation, in that, as expressed in (14), it reflects the possibility for an expression to be *interpreted in terms of another expression*. In this it moves fundamentally beyond the Saussurean sign. The representation in (15) makes this more precise by revealing the mechanism involved: The possibility for any number of occurrences of variables to be identified and to be bound by the same element (acquiring the same restriction).

Note that this appears to give us two notions of a variable, one resulting from translating pronouns, the other one reflecting the openings in a concept along the lines discussed earlier. The pronoun is a linguistic expression, endowed with features such as person, number and gender, hence it seems rather different from an opening in a concept. This dual status directly touches on the legibility issue.

Together, this suggests a unified conception of linguistic variables as Janus-like elements: one face reflects the 'opening' in a concept, the other face reflects syntactic properties. In this sense, they do reflect the duality of the Saussurean sign. It is the latter face that carrries the syntactic properties making it legible.[32] In line with linguistic practice I will use the term *feature* for the latter (but note that, features are in fact just properties).

It is important to distinguish between what should hold by conceptual necessity on the one hand and the implementation that is particular to language on the other. What holds by conceptual necessity is that concepts like *brown* or *bear* have openings. Given that these openings can be manipulated by the language system (valued, identified), it is also necessary that they are legible as in (16a). However logically one could conceive of systems where the legibility requirement would be trivially satisfied. This however, does not appear to be the case in human language. In our language system, legibility is specifically implemented as in (16b):

(16)

a Variables should be legible to the syntactic computational system.
b Variables have one face endowed with morpho-syntactic features.

It is the *morpho-syntactic features* of (16b), then, that *make variables legible*.[33] This is a contingent property. One may, then, wonder whether there is nevertheless some rationale for their choice. In (6) above, repeated here, I summarized the role of the motor system:

(6) *Finding its grip on the form-side of lexical items as instructions for (delayable) realization, the motor system combines and recombines them, yielding complex expressions that serve as input to the interpretation system.*

This entails that in order to be legible an element must have a link to the form side. On the other hand, whatever link it has must be compatible with its role in the semantics, as a variable. It is the morpho-syntactic features that provide the link with the form system, but their contribution to interpretation is so limited that it is compatible with representing the openings in a concept.

Where languages may in principle differ, is in the type of features legible variables carry. It is striking that many languages use a limited set of features to represent variables as independent items, and/or express the linking between elements. This set typically includes so-called 'pronominal features' (abbreviated as

[32] It is good to distinguish between two uses of the term property: property in the sense in which the word *brown* semantically represents a property and the term in our syntactic meta-language.

[33] This helps resolve a question that comes up within the minimalist approach to grammar (Chomsky, 1995). If the linguistic computational system is the optimal solution for a mapping between the Form system and the Interpretation system, why does it use features such as Case, and phi-features on verbs adjectives, etc., that don't make an immediate contribution to interpretation? Aren's these inexplicable imperfections? The answer is that it is this type of formal feature that is necessary to bring about legibility.

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phi-features), such as person, number and gender, like what we see in the pronominal systems of many languages (*I, you, he, she, it, we, you, they* in English) but also in subject-verb agreement, or adjective-noun agreement in languages having it. Note that, prima facie, agreement in, for instance, Bantu languages, is based on different features, such as noun classes. The set also includes Case, but also theta-features in Reinhart's sense (themselves legible by assumption) may contribute to legibility of the elements carrying them. Such feature bundles, then, can be viewed as *Canonical Structural Realizations* (see Grimshaw, 1981) of the *openings* in concepts. It is conceivable that in the end we will be able to say that, morpho-syntactically, variables are universally phi-feature bundles, as indeed in many languages appears to be the case, but for the moment (16) is all we can derive from our assumptions.

Further pursuing this issue would lead us beyond the scope of the present contribution. But, even so, we have made a significant step towards an understanding.

Having established what we did, we can go back to one issue that was left open:

(17) By what mechanism are the variables in a binding configuration as in (15) identified?

The main idea behind the concept of a variable is that it is precisely that: a variable. That is, no restrictions on the values it can get, but for what is derivable from the context. Conseqently, nothing will prevent a variable from getting valued by being substituted for by another variable (unless we rule this out by stipulation). Let's formulate this a bit provocatively as in (18)[34]:

(18) Variables can get other variables as their values.

Since (18) follows from the conception of variables as such, it is not an independent innovation, but it is what we need to explain the core property of language that expressions can depend on another expression for their interpretation. *Having legible variables is all that is needed to achieve this.*

This raises the question of how to deal with variable types. The notion of a variable reflects the ability to receive any suitable value. Such values are not by necessity restricted to individuals. In fact, in our earlier discussion I already sneaked in the notion of an event variable in (8). Event variables are typically associated with verbs. In our initial discussion I contrasted the relation between *brown* and *bear* with that between *former* and *chief.* The meaning of former chief is not properly represented by *λx. (chief (x) & former (x))*. What is needed is that somehow *former* applies to *chief*, as in *chief (λP. (former P))*, with the result 'former chief' applying to x, as in *λx. ([former chief] (x))*. In a nutshell, the opening in *former* is not an individual variable but a variable ranging over properties. Given this, do we need more than one type of variable, and if so, would more than one innovation be involved?

It is easily seen, that such type restrictions don't need to be stipulated. It is the meaning/'the concept' of *former* that is enough to ensure that the interpretation of *former chief* as *λx. (chief (x) & former (x))* is nonsensical.[35] But syntax is not concerned with sense or nonsense, witness *square circles* and the like. So syntax doesn't care whether *former* applies to an individual variable (with a nonsensical interpretation) or a property variable (with a reasonable interpretation). This entails that at the level of the interface between syntax and the interpretation system, there is no need to distinguish between variable types. In a nutshell:

(19) From an evolutionary perspective the emergence of only one legible variable type suffices.

I will conclude this part with a brief discussion of two further issues that touch in specific properties of the language system. Readers that are more interested in general issues may skip these and move directly to the conclusions in Section 7.4.

7.3.1. *A structural condition on variable binding*

Variable binding is subject to a structural condition, namely *c-command*. Intuitively, the binder must be a sister to a category containing the element to be bound.[36] In terms of the structure building process we assumed, the binder must have been merged with the constituent contraining the bindee. This is illustrated by the contrast in (20):

(20)

a [[The chief [who found *the thief*]] [killed ***him***]]
b *[[The chief [who found *every thief*]] [killed ***him***]]

In (20a) *the thief* and *him* can both be assigned the same individual as their values. As we saw in the previous section, this involves two instances of independent access to the discourse system, which happened to retrieve the same individual, effecting coreference. In (20b) *every thief* cannot be linked to a discourse individual since it is quantificational. Hence the only way *him* can depend on *every thief* is by binding. The relevant notion of binding can be defined as in (21), following Reinhart (2006):

(21) A-binding (Reinhart, 2006)

α A-binds β iff α is the sister of λ-predicate whose operator binds β

So, for instance in (14/15), repeated below, *No warrior who has a spear* originates as a sister to the predicate containing *he*. It ends up as a sister to the λ-predicate *(λx. (x doubts that x will attack))* in the sense of (21), and A-binds both variables, formally expressing the dependency indicated in (14).

(14)

[$_S$ No warrior who has a spear (x) [$_{Pred}$ doubts that he will attack]].

(15) No warrior who has a spear [$_S$ (λx. (**x** [$_{Pred}$ doubts that x will attack]))]

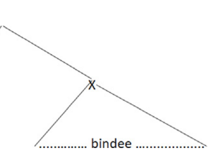
In (20b), though, *every thief* is not a sister to the predicate containing *him*. Hence it cannot subsequently become a sister to the λ-predicate containing *him*, and therefore cannot bind the latter.

Ideally, the c-command requirement on A-binding should not need to be stipulated, but follow from other factors. Reinhart (1983) suggested that the sisterhood requirement followed from semantic composition and economy. Pursuing this idea, note that the c-command requirement on binding resembles that on dislocation/remerge. Remerge also moves a phrase to such a position that it becomes a sister to the structure originally containing it. Note now that in order to get the binding configuration in (14/15) one step is that the expression *no warrior who has a spear* gets to be detached from its variable. Assuming this detaching involves movement, any restriction on movement will be inherited by the detaching operation and hence by binding. Hence, no specific innovation is involved in the c-command condition on binding.

[34] In order to avoid misunderstandings, I should stress that (18) only applies to a conception of variables as grammatical objects along the lines discussed, and not for a conception of variables in the usual semantic meta-language (thanks to an anonymous reviewer asking for clarification).

[35] An anonymous reviewer takes issue with this discussion of *former*, saying that "If we use the common assumption that "former" denotes a function from properties to properties, there is no way to get a representation like the "nonsensical" one that R mentions.Ït is correct that we don't get this *interpretation*. However, the text question is whether this property of *former* has to be encoded in the syntax in the form of a special typing of the variable. To this question the answer is negative, so the nonsensical representation is not syntactically excluded, nor is there a need to.

[36] As illustrated in (i):



The other general issue is that of lexical classes, such as Noun, Verb, Adjective and Preposition.

7.3.2. The status of lexical categories

There is a long-standing discussion whether there is a universal set of lexical catagories, and if so how they are defined. Chomsky (1970) develops a proposal to define them in terms of two binary features [+/−N, +/−V] (see also Jackendoff, 1977), where nouns are [+N,−V], verbs [−N, +V], adjectives are [+N,+V] and prepositions are [−N,−V]. The issue has also been widely addressed in the typological literature, where often doubt is expressed about the universality of this set (see also Baker 2003). From the perspective sketched in the present discussion, one obvious question comes up: If these categories are universal how could they have arisen, and become part of the language faculty? Clearly, that they could have arisen from a separate discontinuity would be quite unlikely. One possible – and not impopular – line is that the classes are rooted in the semantics. For instance, one could argue that nouns refer to prototypical objects, whereas adjectives don't. However, this obviously doesn't work, since the interpretations of nominal expressions are quite disparate. It is hard to see what *bear*, *tree*, *hunt*, *beauty*, *annoyance*, and *examination* have in common semantically. From the perspective of semantic structure, however, common nouns are not only similar to each other, but also to adjectives: all denote properties.

Let me make a suggestion based on ingredients we already have. In the languages that clearly show a diference between nouns and adjectives two contrasts are striking. Whereas there are 'typical' adjectives that take property expressions as arguments (such as *former*, and *alleged*), there are no 'typical' nouns that do so. And whereas typical nouns may take a determiner to become usable as an argument, typical adjectives require a bit more. So in English what could be expressed as *the brown* on the model of *the bear* is in fact expressed as *the brown one*. In Dutch we find the requirement of overt agreement morphology although there is no head noun to agree with (Kester, 1996).

Together this indicates that the core issue may reside in the legibility of the variables involved, more specifically, the innermost variable representing what Zwarts (1992) calls the *referential argument* – the variable in *bear (x)* or *brown (x)* (see Zwarts (1992), and Winter and Zwarts (2012) for more recent discussion). As they argue, this referential argument is never syntactically realized as an independent argument. However, it can be bound by for instance a determiner. From the present perspective this entails that it must be legible. This legibility is, then, reflected in the phi-features these expressions carry. This suggests a handle on the noun-adjective contrast. Nouns can occur by themselves, adjectives occur in noun phrases and agree with nouns. And, in case they are used 'as substantives', this must be licensed by some other means (e.g. 'one'-insertion, or specific morphology, see Kester, 1996). This suggests a very minimal formal property to distinguish nouns from edjectives: lexical items representing properties that make their referential variable legible without further ado are nouns; lexical items such as *brown* that cannot make their referential variable legible by themselves are adjectives. Adjectives, then, agree with nouns to make their referential argument legible; the special morphology in case of their substantive use has the same effect. A suffix like −*ness* turning the adjective *white* into the abstract noun *whiteness* does little more than contributing legibility to the referential variable of *white*.

From this perspective the difference between nouns and adjectives reduces to direct versus indirect legibility.[37] And both strategegies may be expected to be universally available. But, since no deep semantic contrast is involved, languages may also be expected to vary in the prevalence of one or the other strategy, possibly also depending on the type of features involved in legibility.

In the Winter-Zwarts approach verbs have two types of variables: the variables associated with the thematic roles, and a referential argument, here the event variable. The thematic variables, then, are legible by Reinhart's theta-features, as discussed above. The event variable as the referential variable appears to be the defining element of verbs.[38] Pursuing the line of the previous paragraph, one may then define verbs as those lexical items that make their referential variable legible as an event variable. Prepositions, finally, are relational, but cannot license an event variable.

Tentative as this may be, it provides a clear perspective on how to reduce lexical categories to features of the grammatical system that are independently needed, and without introducing additional evolutionary steps.[39]

7.4. Summary of discontinuities

Let's now summarize our results so far in terms of necessary evolutionary discontinuities, in the form of barriers that are lifted/crossed by a new connection:*Crossing* i. arbitrariness/coupling: forms (instructions to the motor system) can be handled as proxies for the content they are associated with.

- recursive combinability – (re)merge, check/agree (yes-no property).

Crossing ii. lifting the concreteness restriction on signs and operations

- desymbolization: severing the relation betweeen signs and concepts; functional elements as instructions for interpretation (yes-no property).
- severing the relation between the instruction to carry out a formal operation on a syntactic representation (which by assumption involves the motor system), and the obligation to physically implement that instruction.

Crossing iii. legibility + variables

- Legible variables as the counterparts of 'openings' in concepts; enabling the crossing of the barrier between the concepts system

[37] An anonymous reviewer makes the highly interesting suggestion that understanding the nature of the contrast betweeen nouns and adjectives involves considering more deeply the relation between language and perception. Pursuing this idea would require another project, though.

[38] The question is whether we need two types of referential variables. More parsimoniously, then, the contrast might be reduceable to the nature of the binder, a temporal element in the case of verbs, a determiner in the case of their nominal use. (See also Reuland (2011b) for some discussion from a different perspective.) It is not yet clear, though, how this would work for the relation between basic nouns and nominalizations of verbal concepts. As argued in Winter and Zwarts (2012) on the basis of event oriented adnominals, nominalizations may contain a verbal structure with an event variable as the referential variable, that is embedded in a nominal structure with its own referential variable, which might make unification less straightforward. I would like to thank Yoad Winter for very helpful discussion of these issues.

[39] There are many more issues to be discussed in this context. An anonymous reviewer brings up the contrast between transitive and intransitve verbs and the contrast between mass nouns and count nouns. The contrast bewteeen transitive and intransitive verbs is straightforward and resides in the number of thematic arguments (see Winter and Zwarts, 2012). The fact that count nouns require a determiner where mass nouns don't is a specific property of a class of languages, and is independent of the general ability of nouns to license the referential argument, as we can see in the vast number of languages without articles.

and the computational system (yes-no property); legible variables enable the interpretation of complex expressions.
- one variable type suffices.
- identifying variables enables a core feature of language: expressions can depend on another expression for their interpretation → binding.

What is needed for language as we know it are these three crossings. On the basis of the description they may seem independent. None of them has much impact in isolation. All this already presupposes a sufficient working memory and a conceptual system, along the lines discussed in Section 5. (And note, recursion is a yes—no property; one cannot have just a bit of recursion in a system, but one can have a sketchpad with a limited space allowing recursively specified structures to be used). What they share, though, is the lifting of a barrier. If so, it is conceivable that language just resulted from one discontinuity, namely the simultaneous lifting of a number of barriers between components of the cognitive system. Alternatively, all three events are indeed unrelated, occurred independently, and accidentally, but only got an impact when the third one occurred.

What we have seen indicates that a sufficient working memory – as one can assess on the basis of tool making – is indeed a prerequisite for language, but that at least three further conditions must be met. These cannot be reduced to a working memory that is just more of the same. So, drawing conclusions about language on the basis of tool making as is occasionally done is not warranted. But, perhaps the crossings can be reduced to a qualitative leap in the nature of working memory: *the ability to deal with different types of information at the same time*. If so, this would be the single discontinuity one hopes to find.

In this contribution I focus on a functional analysis of the evolutionary process, and the discontinuities it must have involved. An important challenge is to determine genetic changes that relate to these discontinuities. One would hope we can at some point. Evolutionary genetics is a rapidly developing field. Berwick and Chomsky present a fascinating overview, to which I am happy to refer the reader who wishes to explore that field.

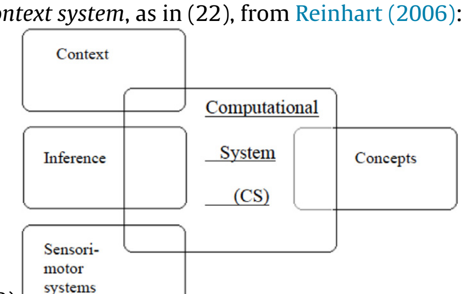
7.5. *The time frame*

An intriguing question is the time frame. The most plausible position is to take the event of the migration of a group of modern humans out of Africa as the point before which a 'language ready' brain must have been present at the latest. Most researchers put this event at around 70 ka BP, but little has been said about an earlier date *ante quem*, or a certain and informative date *post quem*. Berwick and Chomsky mention 200.000 BP, which marks the appearance of the first anatomically modern humans in southern Africa, as a reasonable date *post quem*, and give the appearance of the first behaviourally modern humans in Southern Africa (as evidenced by the findings in Blombos Cave) around 80.000 BP as a reasonable date *ante quem* (see Berwick and Chomsky for further pertinent discussion[40]). This coincides with the dating of complex hafting discussed by Lyn Wadley (see Section 4.2).[41] It seems then that what we can say with a reasonable degree of certainty leaves us only with a fairly limited time window for the discontinuities as summarized in Section 7.3 to have arisen.[42]

Note, that it is very hard to link the availability of language with any degree of certainty to the type of non-linguistic behaviour we have direct evidence of. Even if the ability to control fire or the ability to carry out complex hafting operations indicate that certain prerequisites for language have been fulfilled, the functional analyses performed don't indicate that they require language – although, as mentioned, Wadley (2010) argues that certain types of complex hafting techniques could not have been transmitted without language. And in fact, Wadley's suggestion is the way to go. One may try to identify achievements – for instance complex seafaring endeavors – that require a degree of coordination betweeen the participants that is impossible to realize without language. Although in principle possible, to my knowledge, this hasn't been done yet.

8. Imagination unleashed

Given the tools discussed, we have recursive combinability and principles enabling the interpretation of the structures produced. The interpretation rules are insensitive to plausibility or implausbility, sense or nonsense. They as easily combine *brown* with *bear* as *square* with *circle* or *white* (or *black*) with *hole*. A stone may jump, a mountain may hear. In short what we have is *imagination unleashed*. In order to see the full potential of this result, consider the relation between the computational system and the interpretation system in more detail. As came along in our discussion, the expression *brown bear* has a different status than *the brown bear*. The latter requires for its interpretation access to the context of utterance, as in 'value the expression *the bear* with the individual in the context of utterance who is a bear' (see Section 7.1). An expression like *The brown bear is dead* is of a yet different sort than the expression *the brown bear* or *the dead brown bear*. It expresses a proposition that can be evaluated as true or false, relative to time and place of utterance. Propositional structures minimally contain predicates (such as *grunts* and *is dead* and arguments such as *the bear*), but the crucial factor linking them is predication, and linking the relation expressed by the latter to relevant points in space and time. To achieve this not only arguments and predicates, but also Force (assertion, question, etc.), and a temporal dimension must all be simultaneously be represented and be available for the computation. In a nutshell, linguistic computations need not only be able to access the conceptual system (and the inference system), but also the *context system*, as in (22), from Reinhart (2006):



(22)

This requires the ability to place an event, and also oneself as a speaker, in space and time. As we saw earlier, discussing the limits of 1st generation imagination, language does not only allow us

[40] Note that this is after the split betweeen *homo sapiens* and Neandertals (dated at around 400–600 ka ago), which would leave the Neandertals without language as we know it, but see Wynn and Coolidge (2007) and (2012).

[41] The traces of controlled fire dating from 400 to 300 ka BP discussed in Roebroeks and Villa (2011) were found in Europe, hence from the wrong place and time to plausibly bear on the existence of language.

[42] Bob Berwick (personal communication) pointed out the possibility of pushing back the date *ante quem* on the basis of genetic analysis, by identifying human populations that must have diverged at times prior to the out of Africa migration. He drew my attention to Gronau et al. (2011), who argue that this is the case for the San population of southern Africa, which they claim diverged from other human populations approximately 108–157 thousand years ago.

to speak about the here and now, but also about past events and possibly future events, thus positioning such states of affairs on a dimension of time. Our imagination not only allows us to position such states of affairs on a dimension of time, but also to position our selves – our awareness – in such states of affairs, effecting mental 'time travel' (see Tulving 2002).

In order to get there, we must apply the same logic as Reinhart did in the relation between language and the conceptual system. On the one hand, we have the extralinguistic side. For the emergence of a *time* axis, nothing more is needed than a WM able to retain that two events occurred in a sequence, and the subsequent organization of temporal sequentiality into a recursive structure. For a *self* perhaps nothing more is needed than the ability to access and manipulate representations of one's own belief states. However, *subjective time will* require more, namely once more crossing a barrier, putting one's self as an observer of a past or future event, and making representations of the context of utterance legible to the computational system. Essential is a coordinate system in a legible format. Such legibility, then, entails the ability to isolate and access one's own belief states just as 'normal' independent objects, or as Tulving calls it, *autonoetic awareness*. And, again, we may have a fourth crossing; but from a perspective of parsimony, one change lifting the barriers between subcomponents of the cognitive system may well be the event that made it all possible.

This then is what was needed for 2nd order imagination to arise. Creating sentences and positioning them in every imaginable context and place, as in the examples at the end of Section 5, repeated here.

(1)

a A square circle
b That every hunter who saw it hit some bear that chased him.
c That the chief's father told him yesterday that tomorrow's hunt will probably be much better than his last hunt the year before.
d That the priest will probably like to have her first food at sunrise tomorrow morning.

9. Dependencies galore

Characteristic of language is the prevalence of dependencies. Just like the interpretation of a composite expression depends on the interpretation of its component parts, the form of one expression may depend on the form of another expression.

Examples abound. In many languages the form of the inflected verb depends on formal properties of the subject. In English, for example, we find *I walk*, but *John walk**s***. As objects of verbs, we find not only noun phrases, but also full sentences. As modifiers of nouns we find adjectives, but also full relative clauses. As modifiers of clauses we find not only adverbs, but also, again, adverbial clauses. These in turn contain noun phrases and modifiers, etc. So we find sentences within sentences, noun phrases within noun phrases, etc.

One type of dependency is often singled out in discussions: namely nested dependencies, in which a category of a certain type is embedded in a category of the same type, etc. This type appears to be subject to restrictions, which in turn led to a debate about how crucial recursion effectively is.

9.1. Recursion and 'flattening'

Since Chomsky and Miller (1963) it has become well-known that certain nested dependencies provide a problem for the human processing system, as illustrated in (23), which as anyone will see is difficult:

(23) #The rat [the cat [the dog chased] hurt] died.

This is occasionally used to argue that the human language system cannot really handle recursion. Such a conclusion is unjustified, however. A flattened counterpart of (23) in which the embedded relatives occur on the right presents no particular processing difficulties:

(24) The rat died that the cat hurt whom the dog chased.

Crucially, interpretively nothing has changed. The phrase *that the cat hurt*... still modifies *the rat*, the phrase *whom the dog chased* still modifies *the cat* and the interpretive system has to accommodate all that, and put the dislocated phrases right back in their proper place for interpretation purposes. Consequently, this flattening requirement can only reflect a property of a sub-part of the language processor – specifically involving the memory system of forms – but cannot reflect a property of the grammatical system per se.

In fact, if one looks carefully, one sees that recursion applies in many different domains.

9.2. Recursion across domains: the sky is the limit

That the formation rules of linguistic objects apply to their own output we observed in sentence formation: combinability applies to elementary and composite syntactic objects. But we see it also in word formation. Virtually any piece of composite meaning can be squeezed into a word. Anything from basic objects (cave), to properties of objects (warmth), events (work, hunt), properties of events (success), complex events (beautification), etc. can form a possible argument, and anything from a basic event description (eat), to a property description (beautify), to a noun (carpet), can be made into a possible predicate. Anything from **basic concepts** to **higher level instructions for interpretation** may serve as a possible interpretation. We have meanings as mental objects reflecting the result of perception, but also as instructions applying to the formal representation of such objects, or instructions applying to such instructions, at infinitum.

The net effect of this recursive combinability in all domains, is that imagination escapes from the obvious. The immediate sources are the following properties.

Syntactic categories are blind to type of concept

We form nouns and verbs as illustrated below: individual (*John*), mass (*water*), or event (*attack*), abstract (*beauty*) or concrete, simplex or compound, behaving as dictated by their category, not by what is represented.

- Nouns: rock, spear, bear, circle, beauty, courage, zero, pi, humanities, hunt, walk, annihilation, antagonization, killing, ...
- Verbs: arrive, walk, hunt, make, beautify, antagonize, rock, spear, zero, annihilate, antagonize, kill, ...

Interpretation rules are blind to sense or nonsense, expected, or unexpected:

- Modification treats *brown bear* on the same footing as *square circle.*

Modification: [[$_{\text{Adjective}}$ brown] [$_{\text{Noun}}$ bear]]
[[$_{\text{Adjective}}$ square] [$_{\text{Noun}}$ circle]]

- Predication treats abstract nouns on the same footing as concrete nouns, and blindly ascribes a property.

Predication: [[$_{\text{Noun Phrase}}$Hector] [$_{\text{VerbPrase}}$ killed the bear]]
[[$_{\text{NounPhrase}}$ beauty] [$_{\text{VerbPrase}}$ killed the hunt]]

The fact that interpretation rules are not restricted by plausibility or by expectations – contrary to what usage based approaches would lead us to expect – bringts us to the very foundation of

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human creativity, and puns (with profound implications for current debates about linguistic methodology).

10. 2nd generation imagination and beyond

The interplay of combination and interpretation allows us to first create novel combinations of forms, and then:

- apply fixed rules to determine the interpretation of these combinations (and note, if the effects of the rules were not fixed, they would not allow us to escape from the conventional). (See also Hinzen (2008:xiii): "*The point of language*... *is* .... *actually to free our mind from the control of the external stimulus*..."; thanks to Andrea Moro (p.c.) for drawing my attention to Hinzen's remark).
- determine if there are objects or events, moods, emotions, or anything in our mental universe corresponding to them.

This yields a new mode of imagination: *the language lab*, producing both science and poetry.

The fact that interpretation rules apply blindly is not without its occasional drawbacks, as illustrated by the use of the following interpretation rule:

(24) Given a definite description: find and assign the referent.

Thus, given a name, the language user will apply the interpretation rule: look for a referent.

Blindness of rules, then implies the strategy: there must be a referent, just look for it. This rule has profound implications for rethoric and spinning, as it leads to the ubiquitous 'name and existence fallacy':

(25) *Name & Existence fallacy*

This is a "name" hence there exists an entity it is the name of:

- Humanities
- 5D Jeans
- European culture
- The Dutch identity
- The Dutch values
- "The" Dutchman
- The typical male
- - - - - - - -

All these expressions have led to tons of wasted paper, successful advertising campaigns, heated political discussions, discrimination of immigrants, and (too) fashionable research programs.

So, applying fixed interpretation rules to combinations of expressions enables human imagination to transcend the initial boundaries of the imaginable. Thus language enabled the transition from a 1st generation imagination to a 2nd generation (and perhaps even higher orders of) imagination.

- 1st generation imagination: Manipulates representations of observable objects on visuo-spatial sketch pad in terms of primary properties (lines, surfaces, colors).
- 2nd generation imagination: Manipulates derivative representations: combine forms freely, interpret the result by fixed rules, interpret with disregard for plausibility and then explore its possible uses – from black to white holes, from natural numbers to imaginary numbers, from Euclidean to non-Euclidean spaces.
- Leads to the development of the formal languages of mathematics and theoretical physics, etc.
- Leads to philosophy, metaphysics and religion, including omnipotent creators, saviors, prescripts, and afterlives.
- Leads to much of our societal superstructure, including Euro-crises, credit crunches, and management-induced stress.

11. Towards a paradox

One of the recurrent themes in the study of languages is that of unity versus variation. There is unity in the basic design features sketched (arbitrariness, recursion, word formation, meanings from concepts to meta-instructions, fixed blind interpretation rules – modification, predication, relation to discourse). But there is much more. Many conceivable properties of language-like systems are never realized in languages as we know them. But it is still a non-trivial task to reduce the general properties we find across languages to the design features mentioned, if possible at all. We see variability in the sound systems. We see varation in richness of inflection (case, tense – English, Dutch, German, Russian, Latin). We see variation in word order (compare English to Dutch, Russian, or Latin to mention a few). All even within one language family. We see variation in anaphoric systems. But, wherever we see variation in language, there are also clear limits to it. And an important enterprise is to chart these limits and to explain them. For proposals in the domain of word order see Greenberg (1966), and subsequently works like Cinque (2005), or Biberauer et al. (2014) in increasing detail. For a similar endeavor in the domain of anaphora let me refer to Reinhart and Reuland (1993), and Reuland (2011a).[43]

It would lead us beyond the scope of a single article to even present a cursory overview. For now let's identify the problem as the *design gap*: To what extent are we able to reduce restrictions on the variation we see to general design properties of the language system, and/or our cognitive system at large? Ideally we should, since, any general property of language we cannot explain in this manner poses a puzzle from an evolutionary perspective.

The design gap also leads to a fundamental question of a different nature: How flexible is the human mind in the face of the products of our own imagination? Can we cope with everything our imagination can produce? If the mind were fully flexible the design gap would loose its fundamental nature, since whatever option has not been realized now could in principle be in some future time.

The question is, are there more ways to distinguish between fundamental and the accidental properties. than just in terms of what has been realized in the languages of the world? Let's focus here on one property, the structure dependence of grammatical operations.

From the early years of generative grammar it has been argued that it should not be considered accidental that all operations in natural language have the property of *structure dependence* (see, for instance, Chomsky, 1965, 1986).[44] That is we find no operations that consist of just mirroring an arbitrary string, or fronting the third word of sentences.

For a specific example, consider the formation of yes-no qestions in English. It typically involves the fronting of an axiliary, as in (26) (see Chomsky, 1986):

(26)

a The man is hungry
b Is the man hungry

[43] See for detailed analyses subsequent work like Volkova and Reuland (2014) and Reuland (2016), where it is shown that prima facie very different systems of anaphoric dependencies can be understood on the basis of three simple universal properties of linguistic operations: i. the computational system has trouble handling identical objects, unless they can be kept apart (which entails that Reflexivity must be licensed); ii. linguistic operations must preserve content; iii. the encoding of anaphoric dependencies is subject to an economy principle, which in certain – specifiable – environments gives rise to categorical effects, in others to pReferences

[44] See Berwick and Chomsky (2016) for an extensive discussion of this issue from an evolutionary perspective. Much of what I say here turned out to overlap with their discussion, though not all of it.

What we see in (26) is compatible with two types of rules:
(27)

a Linear: Form the interrogative by moving the first occurrence of the auxiliary in the declarative to the beginning of the sentence.
b Hierarchical: Form the interrogative by moving the auxiliary from the main clause of the declarative to the beginning of the sentence.

For English the two strategies can be differentiated by considering sentences with an embedding, as in (28):
(28)

a The man who is hungry is ordering dinner
b *Is the man who hungry ordering dinner
c Is the man who is hungry ordering dinner

The linear rule would lead to the incorrect (28b), the structure dependent rule to (28c). Chomsky's main points concerning this fact are twofold. One is that the non-structure dependent rule is from a general methodological perspective far simpler than the structure dependent one. The linear rule is *easy* on anybody's count. It can be carried out just on the basis of a property that is directly identifiable without any analysis of the structure. The hierarchical role makes reference to a nontrivial structural property, namely *main clause*. The other is that this is not just a quirk of English, but a general feature of natural languages. No language could, for instance, form yes-no questions by systematically putting the verb after the third word as in (29):
(29) Language X (rendered by glossing):

a The man from Siberia **drew** a portrait → Q: The man from **drew** Siberia a portrait?
b The old man from Siberia **drew** a portrait → Q: The old man **drew** from Siberia a portrait?

The rule is again very simple. Yet, it seems pretty absurd. But why? And even if it is absurd, and is not used in any language, could it be acquired, and if so what would this tell us about the nature of language? What happens if imagination enters the picture? *We can imagine such an absurd 'linear' language. I just did!* What is, then, the status of the fact that we find no language that does it that way? Couldn't that be accidental? The ancestor of current surviving human languages didn't have this property, hence no living language has it? How can we choose between **accident** and **design property**?

An important window into these questions has been provided by our ability to handle invented languages – languages that come from a 'drawing board'. See what happens if we teach human subjects a language with rules that violate this structure dependence. We may formulate this as an even more general issue:

(30) How free is the human mind in coping with systems that come from its (= our) own drawing board?

This brings us to the last group of issues discussed in this contribution: The limits of imagination. From Thomas More's Utopia to the architect Le Corbusier, who developed overarching visions of urban architecture. The next picture shows Le Corbusier's view of a town plan superimposed on Paris (Picture 8).

The town plan shows a cadence of ever-repeating elements, as a manifestation of and a tribute to the industrialized society. In this view design follows from economy. This view was not realized in this form, and most luckily not on Paris. It reflects the aim to subordinate man to a concept grounded in economy. A crucial question is then if it would have been livable. Le Corbusier is not unique. Endeavors to subordinate humanity to a concept reflect an ever-recurring desire up to the present day. So, how flexible are we?

Leading up to further discussion of this crucial issue, let's briefly consider two well-known case studies involving language. The claim that structure dependence is a fundamental design property of human language, coupled with the fact that language acquisition is only possible given a restriction on possible grammars (a restriction on the 'space of hypotheses' that can be considered by the language learner, i.e. Universal Grammar) and that this hypothesis space better reflect the fundamental design properties of language, together make a clear prediction: *Languages violating structure dependence should not be learnable in the same way as natural languages*.

More specifically, language acquisition is by and large independent of general intelligence. But, to the extent in which rules of language violating structure dependence can be acquired, this should be sensitive to general intelligence. This idea was corroborated by a famous study of the performance on such tasks by Christopher, a language *savan*t, reported in Smith and Tsimpli (1995), who failed on non-structure dependent rules. Musso et al. (2003), Tettamanti et al. (2002), and Tettamanti et al. (2008) carried out a series of experiments on acquisition and processing of an artifical language, *linear Italian*, involving brain imaging techniques; see Moro (2008) for an extensive overview and discussion. The upshot of these experiments is that there is indeed an important difference between the way langages with non-structure based dependencies – linear languages – are handled as compared to those with structure based dependencies. The latter for instance, will involve Broca's area, whereas the former does not. Non-structure based dependencies, once acquired, will require more effort, and be processed less efficiently.

It is such investigations that will help us close the design gap by relating identifiable general properties of language to the working of the brain structures subserving language.

12. Language and beyond: from imagined languages to imagined societies

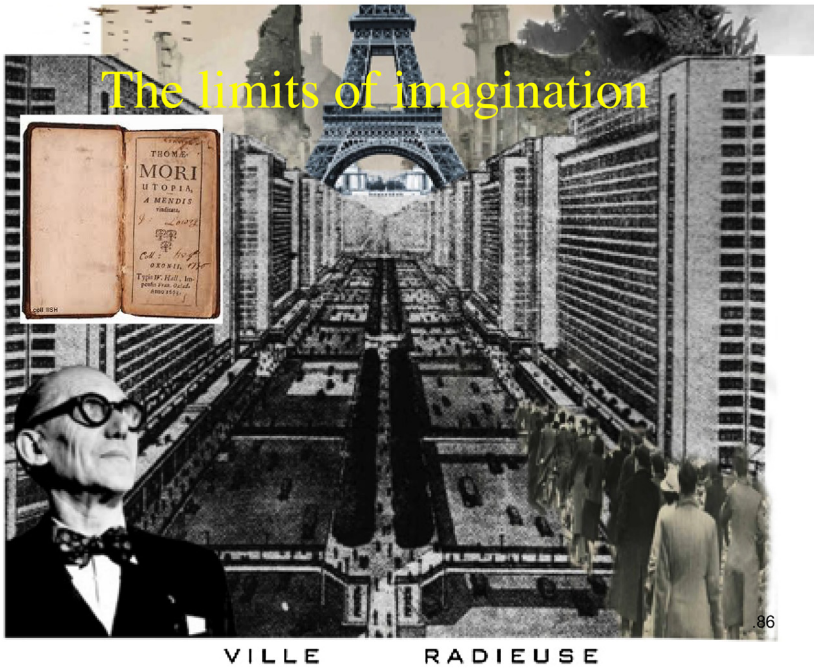
These results show that we can imagine linear languages, and investigate how our cognitive system copes with them. Considered in isolation, their rules are simple, the *typical simplicity of the drawing board*. Moreover, our cognitive system is able to cope with them. But, with an important proviso: linear languages are not processed as efficiently as natural languages. This leads to the following conclusion:

(32) Drawing board simplicity need not correspond to a simplicity that is effective for the human mind.

In turn this shows that there are limits to the freedom of our minds to deal with the results of our own imagination. Does this apply to all drawing board languages? Not necessarily. An invented language such as Esperanto can work since it is organically designed. It has been unconsciously based on principles found in natural language, and therefore largely reflects "natural economy".

The fact that there are limits to the freedom of our minds to deal with the results of our own imagination has profound repercussions more generally. Through the ages philosophers, theologians, and politicians, have come up with proposals for societies from the drawing board, that is, societies dedicated to the worship of some higher force, or for more "rational" or "just" societies, such as Plato's State, or Thomas More's Utopia (with shared property, no differences in income, each citizen is assigned 'the best' job, etc.).

We have seen light forms of engineering during the spread of Roman civilization, the subsequent spread of christianity in Europe, and at times during the spread of islam. But also strong form of religious engineering such as Calvin's mid-16ths century Geneva. From the 19th century on we have seen a range of attempts at social



Picture 8. The limits of imagination.

engeneering from a 'rational' perspective. To my knowledge, there have been no attempts to literally realize Plato's State of Thomas More's Utopia, but major attempts to engeneer societies inspired by a (purported) form of Marxism, while fascist ideologies provided a yet different basis. It seems fair to conclude that these all failed in one respect or another. All these attemps exemplify that *one part of our mind cannot deal with what the other part comes up with.* And over the last few decades, we have been seeing once more the emergence of religious beliefs as a basis for societies in the middle east. In these too we see a tension between what some people's minds can come up with and other people can cope with.

As is easily observed, current bureaucratic societies as we see them in the West, have a high drawing board character. Despite their apparent successes, they are failing in significant respects. In view of what we know about the human mind this should come as no surprise. It is striking that, even if the rules are devised with the best of intentions, the drawing board is not doing better than it does. Simple processes turn out to be not as simple as they might initially seem, and the drawing board evokes resistance.

We can be sure no 'ideal' society will ever emerge. That should, however, not keep us from trying to improve on what there is. But, in doing so, one better avoid the deceptive simplicity of 'linear language-type' solutions, appealing as they may seem to some. The question is, do we need new concepts to think of an alternative to drawing board rules? What is the equivalent to an "Esperanto-approach" in managing organizations, and administrating complex societies? Looking for it, it may seem a bit outlandish. Upon a bit of reflection, however, it may not be so outlandish after all, but involve one of the core notions in human nature, namely *justice*, the balancing of the individual freedom with the needs of cooperation, and the ability to handle the rules one is supposed or even forced to play by.[45] A sense of justice can be thought to be innate, and as crucial as any trait we share in characterizing what makes us human. But as such it is also in a constant struggle with the forces embodied in power and privilege upsetting this balance as we can all to easily observe.

Although the concept of justice is natural, investigating the effects of ever more complex bureaucratic rules and the balancing and rebalancing it involves, in view of the new challenges that contantly face us is non-trivial. It is as non-trivial as investigating the language faculty, and other faculties of the mind reflecting our human potential. In short, its investigation requires a real 'humanities lab', investigating what led us from simple tools to complex societies, including structured products, aleatoric music, abstract painting, and clip culture, and in general what free, unconstrained play with imagination yields. Thus conceived, the exploration of human imagination at all levels and modes from music to history, and from painting to language – in the 'anarchy' (or what is left of it) of art schools and universities – is not a luxury – as the current funding systems apparently judge it – but a precondition for an understanding of us and our society. This brings me to the end of this contribution:

[45] Many of the examples of the absurdity of burocratic rules are easily understood as violations of our sense of justice. To give a few examples, it is our sense of justice that is violated when a train driver is fired when he violates some rule when in fact he is acting for the well-being of his passengers in the situation of an emergency. It is our sense of justice that is violated when school teachers are no longer allowed to teach but are told to 'supervise', against their professional insights and standards, due to some fashion among the administrative forces. It is our sense of justice that is violated when in the name of progress a new law is implemented that all of a sudden makes the quality of your life depend on whether you live 10 m to the east or to the west of an arbitrary line you could never before imagine the relevance of. It is our sense of justice that is violated when one employee receives millions in revenu – based on blind remuneration rules – due to cutting thousands of other employees from their jobs. It is our sense of justice that is violated, when justice becomes a commodity instead of a right. A few years ago a colleague of mine wrote a book *Waarom is de burger boos*? (Why is the citizen angry?) (Rossum, 2010). In his view there is a paradox in that we never had it that good, and yet people are massively complaining. But that is only paradoxical given a particular measure of how good we have it. If justice is our measure, the complaints reflect a rational assessment. For some reason that the degree of justice and control of one's life is decreasing, and that people are very uncertain where this will end.

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13. Conclusion

An increased working memory together with recursive combinability and legibility across domains has unleashed human imagination. But:

- One part of the mind can come up with creations the other part of the mind has trouble dealing with.
- The human mind is not infinitely malleable
  - unlike what bureaucrats (want us to) believe.

- Pushing drawing board policies as "the best and only options" with disregard for core human factors will not lead to viable solutions.

Therefore, exploring the limits of (how we can deal with the products of) imagination, in science, society and art should be one of our primary concerns. And, far from being a luxury for our society: *The humanities' lab is as crucial as the physics lab*.

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