Dicisigns and Cognition

The Logical Interpretation of the Ventral-Dorsal Split in Animal Perception

The sciences of logic, psychology and linguistics have developed, to a large degree, independently during the 20th Century despite occasional, more or less thorough, attempts at interdisciplinarity between them. Modern logic only came into being in the decades around 1900 based on a stance against psychologism, that is, against the interpretation of logic as a sub-branch of psychology. Bolzano, Frege, Peirce, Husserl, Russell all, in different ways, insisted that logic could not be a part of psychology, as that would undermine its claim to validity. Conversely, psychology has tended to take a disparaging view of logic, seeing it as "logicism", remote normative philosophical reifications of things better studied empirically (e.g. Elqayam & Evans 2011).

       Thus, it is not without sense when the linguist James Hurford claims, in a BBS target article (2003), to be the first to drill a "... 'wormhole' between the hitherto mutually isolated universes of formal logic and empirical neuroscience" (Hurford 2003: 261) - continuing this initiative in his major two-volume work *The Origins of Meaning/ The Origins of Grammar* (Hurford 2007, 2012) integrating logic, cognition, linguistics, neuroscience, ethology, and evolutionary biology in a grand synthesis. Here, let us focus upon his proposal as to the role of logic in prehuman cognition. Logic, of course, is chosen as the better candidate to chart prehuman thought because linguistic categories may be, to a large extent, human-specific and thus not immediately applicable to

animal cognition, while logic has the broader scope of covering valid thought processes as such. Hurford's main idea is that prehuman cognition, particularly primate cognition, may be described in terms of a simplified version of first-order predicate logic. So, his argument is not that logical structure is needed for animal communication purposes - it is at stake already in the structure of animal perception. In Hurford (2007), he summarizes the idea there are two logico-neural links, as follows: "... (1) the link between dorsal stream, pre-attentional processes, which assign mental indices to a small number of tracked objects, and the individual variables of logic, w, x, y, z which I assume here to be in very limited supply - only up to four available at any one time; and (2) the link between ventral stream recognition areas, where categorization of tracked objects take place, and logical one-place predicates." (Hurford 2007: 103).

So the overall argument takes its basis in the neuropsychological finding that visual information, after its intial processing in the V1 area in the occipital lobe, is projected forward in the brain in two different streams.[1] One, the ventral stream, projects to the temporal lobe, addressing categorization of visual features of the object seen - while the other, the dorsal stream, goes up to the posterior parietal lobe and concerns spatial localization of the object, connected to movement and grasping possibilities in egocentric space. In the literature, the two streams are often called the WHAT and WHERE streams, respectively (sometimes WHAT/HOW), other description attempts include sensorimotor vs. cognitive processing or the "looking" vs. "seeing" stream. While the dorsal stream is fast, and to a large degree preconscious, the ventral stream is slower, seemingly prompted by and hence temporally sequential to the dorsal stream, and closer to consciousness. The overall picture is that the dorsal stream directs attention to locations and subsequently action affordances and objects in the visual field which are, in turn, analyzed and categorized by the ventral stream. The dorsal stream seems to provide a precise online analysis of egocentric visual action space,

less subject to visual illusions than the more semantically heavy ventral stream.

Hurford's basic and ingenious observation is that these two streams seem to correspond approximately to standard basic notions in classical modern logic - Frege's distinction between function and argument in his analysis of propositions (analogous to Peirce's rearticulation of the predicate/subject distinction). Hurford terminologically selects a compromise vocabulary between the two - predicate/argument - but mentions Frege only intermittently and Peirce never. Hurford's argument builds on the summation of a comprehensive amount of neurocognitive findings and hypotheses. Important is Pylyshyn's idea (1989, 2000) that the posterior parietal cortex operates with a small amount of placeholders called FINSTs (for "FINgers of INSTantiation"), not more than 5 simultaneous foci of attention which may, all of the time, be updated and invested by new perceptual material. Thus, in processing a visual scene, the selected few important objects in it are highlighted for further investigation and analysis in terms of predicates by the ventral stream. Thus, visual cognition, in humans and higher animals alike, shapes its result in the logical form of *PREDICATE (x)*. Despite certain issues to which we shall turn below, Hurford's daring hypothesis seems convincing as a first, basic connection between logic and cognition.

This hypothesis fits surprisingly with the Peircean Dicisign doctrine, according to which all cognition able to express truth must functionally make use of the generalized predicate/subject structure.[ii] There are, however, a number of problems in Hurford's hypothesis (many of them, of course, brought out by the commentators in BBS's open review tradition). Our contention is that some of these issues may be better addressed in the Peircean framework which may considerably add to the synthesis which Hurford constructs from different scientific sources.

Hurford, a linguist by profession, spends considerable energy in collecting and discussing recent neuropsychological findings to establish a knowledge base of current understanding of the ventral-

dorsal split. Strangely, he does not offer the same attention to the other source of his construction - logic; Frege is mentioned cursorily but it is as if Hurford's edifice is primarily one of psycholinguistics where logic is called in only as a handmaiden to avoid linguistic anthropomorphic imperialism into the nonhuman realm. This implies that the very status of Hurford's wormhole never becomes entirely clear.

In the beginning of his BBS paper, Hurford attempts to make clear the role of logic in his synthesis: " ... it is to be expected that the basic *PREDICATE(x)* formalism is to some extent an idealization of what actually happens in the brain" (Hurford 2003: 261). This was certainly neither Frege's nor Peirce's idea, both of them taking logic in a strongly anti-psychologistic sense. They did not see logic as a simplistic representation of complex brain processes; rather they saw logic as normative and as a measure-stick which the thought processes of empirical brains would be expected most often *not* to live up to. Hurford's conception of logic is thus as a particular special science whose results do not impinge on other sciences: "Neuroscientists don't need logical formulae to represent the structures and processes that they find" (On "the bridge from logic to language", Hurford 2003: 262.) The results of logic are rather conceived of as a sort of primitive brain science in a period before the investigation techniques developed by cognitive psychology: "Logical notations, on the other hand, were developed by scholars theorizing in the neurological dark about the structure of language and thought" (Hurford 2003: 262). Thus, Hurford misunderstands Tarski's famous truth definition as a fallacious piece of psychology: "But to say that 'Snow is white' describes the thought expressed by 'Snow is white' is either simply wrong (because description of a thought process and expression of a thought are not equivalent) or at best uninformative" (Hurford 2003: 262 What Tarski meant, of course, was that to understand the proposition "Snow is white" is to know the conditions in which that proposition is true. Hurford, in general, is little preoccupied with what motivated both Frege and Peirce, namely logic as a

means to investigate the structures involved in articulating truth claims, both in everyday and scientific propositions and inferences. Instead, maybe because of his linguistic background, Hurford thinks that "up to the present, the only route that one could trace from the logical notations to any empirically given facts was *back through* the ordinary language expressions which motivated them in the first place" (Hurford 2003: 262) - he takes logic as a sort of attempt to describe the mind based on ordinary language expressions. But modern logic was not motivated by ordinary linguistic expressions - quite on the contrary, it was motivated by structures of scientific thought and the idea to find an unambiguous formalization for science, getting rid of the unclarities of ordinary language. Thus, Hurford misconstrues Frege when he says that "Frege 's new notation (but not its strictly graphological form which was awfully cumbersome) allowed one to explain thoughts and inferences involving a far greater range of natural sentences" (Hurford 2003: 262). This was not his main aim - Hurford tends to see logic as a primitive sort of psycholinguistics, not realizing that all sciences depend on logic, be it implicitly or explicitly. In his 2007 article, Hurford seems even more insistent on full-blown psychologism, now as a basic assumption he contends that the "... logico-linguistic enterprise is essentially psychological" (Hurford 2007: 124), implying that logic and language simply form objects of psychology. Which was precisely what the founding fathers of modern logic - Frege, Peirce, Husserl, Russell - denied.

So, initially, our articulation of Hurford's hypothesis would rather turn the other way, so to speak. The reason that basic structures of First Order Predicate Logic can be mapped onto certain brain processes is not that those results were a first approximation to neuroscience nor that logic is a sort of outcome of the brain's evolution and function. Rather, following the Peircean idea of adaptation to rationality,[iii] we would say that it is no wonder the brain functionally displays the logical doubleness of predicates and subject, as this double structure forms the prerequisite for the articulation and expression of truth (and that biological organisms

have a basic survival interest in having a true grasp of aspects of their surroundings rather than none).[iv] So, the fact is rather that the brain has had to adapt, evolutionarily, to first order predicate logic in order to express truths. Hurford vacillates as to the precise status of his hypothesis; as a conclusion to his BBS article, he articulates it in a different way, rather in the direction of the Adaption-to-Rationality hypothesis: "The dorsal/ventral separation in higher mammals is, I argue, an evolved hardware implementation of predicate-argument structure" (Hurford 2003: 281).

An important observation supporting the idea of general structure informing the Ventral-Dorsal split is the fact, addressed by Hurford, that an analogous split is also found in the brain's processing of sound signals in the auditory system (e.g. Buchsbaum et al. 2005). Recently, it has been documented also in the domain of haptic perception, touch (Gardner 2008), as well as in olfactory perception, smell (Frasnelli et al. 2012), presumably the evolutionarily oldest of the senses. Thus, the split seems to be no artifice of visual perception particularly, but rather a mode of cognitive organization across the sense modalities, probably relevant for the so-called "binding" problem addressing how the different modalities are connected, in cognition, to the same objects from which the relevant perceptions stem.

Among non-human animals, Hurford focuses particularly on primates. It is interesting, however, to consider recent findings that the dorsal-ventral split is found not only in "lower" mammals such as mice (Wang et al. 2012), but a related split with a double visual pathway seems to be functioning also in the (otherwise rather differently constructed) avian brain (Nguyen et al. 2004) with a caudal stream for motion vision and a rostral stream for color and form.

This generality of the ventral-dorsal split across sensory modalities as well as across species wide apart in the ancestral tree points to two possibilities: either this split is evolutionary very fundamental in a large range of higher animals, covering all sensory modalities and thus the result of an early adaptation at the

level of a common ancestor (as argued by Nguyen et al. 2004) - or such a split is a fundamental propositional precondition in order for any sensory apparatus to be able to represent true facts in perception. The two possibilities obviously do not exclude each other: if the latter is the case, higher animal brains will simply have had to adapt to basic structures of First Order Predicate Logic.[v]

For all its indubitable merits, Hurford's connection between logic and prehuman cognition comes with certain problems some of which might be eased in the light of the Dicisign doctrine. These issues include the treatment of logical constants and proper names, the object character of the argument/subject reference, the analysis of polyadic predicates, the selection of quantifier types, and the failure to address kind universals, all of these leading Hurford to embrace a dubious feature-bundle ontology of prehuman logic. Let us investigate these problems.

The first issue is that of logical constants where the variable of the propositional functions *PREDICATE (x)* is saturated by a constant, say *PREDICATE (a)* - in the biological *Umwelt* interpretation typically an individual animal or other particular object of interest for the organism. Hurford sacrifices not a little effort to rule out the possibility of such a filling-in – which is strange as the cognition of individual entities and their properties in the animal Umwelt ought to be one of the primary purposes of animal cognition (is this particular object edible or not? is this organism predator or prey? is this conspecific in-group or out-group, dominant or subdominant, male or female, young or adult, and so on). Despite this, Hurford claims there can be no equivalent to constants or proper names in the proto-thoughts of animals: "In a formula such as *CAME(john),* the individual constant argument term is interpreted as denoting a particular individual, the very same person on all occasions of use of the formula. FOPL [First Order Predicate Logic, fs] stipulates by fiat this absolutely fixed relationship between an individual constant and a particular individual entity. Note that the denotation of the term is a thing in the world, outside the mind of any user of

the logical language. It is argued at length by Hurford (2001) that the mental representations of protohumans could not have included terms with this property. Protothought had no equivalent of proper names" (Hurford 2003: 265). Hurford's reason for thus excluding individual constants from animal cognition, surprisingly, is logical: "Control of a proper name in the logical sense requires Godlike omniscience. Creatures only have their sense organs to rely on when attempting to identify, and to re-identify, particular objects in the world. Where several distinct objects, identical to the senses, exist, a creature cannot reliably tell which is which, and therefore cannot guarantee control of the fixed relation between an object and its proper name that FOPL stipulates" (ibid.). In his 2007 article, this claim is baptized and elevated into "The Principled Unknowability of Uniqueness" (Hurford 2007: 128) , and the thought experiment marshaled to support it is that of the possibility of identical twins. Here, the argument is psychological: "So, psychologically, individual constants, as logicians use them, that is as terms uniquely identifying individuals, are impossible because there is no guaranteed reliable procedure for getting to the 'right' referent" (Hurford 2007: 129). So, his overall argument is logical as well as psychological. He also relates ethological evidence. First, in the BBS paper, he relates an observation of the presentation to a young tern of a loudspeaker sounding with the voice of its parents - the young approached the sound of the source and cheeped a response greeting. Hurford claims this shows the young tern is mistaking the loudspeaker for a parent, thus not able to identify uniquely even its own parent: "Obviously, the tern chicks in the experiment were *not* recognizing their individual parents – they were being fooled into treating a loudspeaker as a parent tern." (2003: 266) But the fact that animals (or people) can be fooled obviously is not an argument that they cannot, in other circumstances, be right. Actually, the tern chick *was* able to identify its parent, even by only a single one of its qualities of appearance, namely the individual voice; this would rather be an argument *for* its actual ability to recognize parent individuality.

And approaching the loudspeaker is not equivalent to taking it to be a bird: maybe the chick just moved in the direction of the sound so as to approach the supposed parent, maybe hiding behind the loudspeaker. An additional argument also involves birds: "The victims of parasitic birds such as the cuckoo cannot tell that the egg in the nest is not one that they laid" (Hurford 2007: 131). But here, the deception is due to the spatiotemporal location of the egg, in the nest, along with the other eggs - not to any of its qualities. Famously, cuckoo eggs typically differ in size and color from the eggs of their hosts. So in this case, it is rather the spatial identification-by-location which is at work, in mammals relative to the dorsal identification of subjects by means of the variables of posterior parietal cortex. Hurford indiscriminately seems to imply his anti-uniqueness principle to cover both particular scenarios of perception - and several such temporally distinct scenarios. But within the frame of a single perception scene, the animal must be able to keep track of the object which is invested with (maybe changing) predicates supposedly, inter alia, by means of the independent spatial localization ability. The second issue is whether the animal is able to stably recognize individuals *across* independent local scenes - but in both of the bird cases, there is really nothing disproving that. So the ethological examples prove little. However, the reason why Hurford gives these examples is that he finds that deception as such is irreconcilable with individual constants: "... a (hypothetical) organism with the equivalent of an individual constant in its mental repertoire *would never be deceived* - that is what is meant by 'individual constant'" (Hurford 2007: 135). Now, human beings do have access to individual constants in the shape of proper names but surely are not, for that reason, immune to deception and mistaken identifications. So don't human beings have proper nouns? Indeed, Hurford's principled problem with constants and proper names seems to be of a logical nature, rather than psychological or ethological: "The logical notion of an individual constant permits no degree of tolerance over the assignment of these logical constants to individuals; this is why

they are called "constants." It is an *a priori* fiat of the design of the logical language that individual constants pick out particular individuals with absolute consistency. In this sense, the logical language is practically unrealistic, requiring, as previously mentioned, Godlike omniscience on the part of its users, the kind of omniscience reflected in the biblical line "But even the very hairs of your head are all numbered" (Matthew, Ch.10)" (Hurford 2003: 266). The problem here is that Hurford inherits a conception of logical reference from Russell and Wittgenstein who thought, indeed, that the reference space for logical propositions was the whole of reality. And of course, an animal proto-thinking the equivalent to "There is a tiger" does not thereby address the existence of tigers as a species of the world as such, but the fact that it perceives, now and here, a tiger in its perceptual field, in its *Umwelt*. This is what makes Hurford insist on taking a universe of discourse restricted to one (visual) scene (Hurford 2007: 125-26). This is obviously too narrow, because that would not allow animals to remember and compare individuals across such local scenes, as if they were not, actually, able to recognize close conspecifics, particular locations, etc., a problem Hurford later recognizes and attempts to solve with a feature-bundle theory (below). Here, however, Hurford's immediate obedience to the Frege-Russell tradition is the root of his conceptual problems: constants are taken to refer to fixed individuals in the unbounded space-time of all of reality. As observed by Hintikka, the alternative tradition which he calls logic-as-a-calculus (as opposed to the Frege-Russell tradition of logic-as-a-universal-language), actually permits the selection of Universes of Discourse of highly varied extensions. The very notion of Universe of Discourse goes back to the fountainheads of the algebraic tradition of logic, Augustus de Morgan (1846) and George Boole (1854).[vi] Continuing on Boolean ground, of course, Peirce's Dicisign doctrine claims that propositions refer to a selected Universe of Discourse: "In every proposition the circumstances of its enunciation show that it refers to some collection of individuals or of possibilities, which cannot be

adequately described, but can only be indicated as something familiar to both speaker and auditor. At one time it may be the physical universe, at another it may be the imaginary "world" of some play or novel, at another a range of possibilities" (Peirce and Christine Ladd-Franklin, 1903: 2.536).[vii]

Thus, constant reference in prehuman cognition needs not be ascribed to the whole of the universe, requiring omniscience on the part of the animal (or the human being, for that matter). On the other hand, the relevant Universe of Discourse could hardly be only the particular visual scene of a single group of perceptions only; in that case the animal would not be able to recognize objects from one visual scenes to the next. The relevant maximum Universe of Discourse probably varies considerably from species to species - depending upon and in any case never larger than what Uexküll addressed as the *Umwelt* of that species. Within that *Umwelt*, pragmatic situations may single out smaller Universes of Discourse; when the vervet monkey cries his alarm signal of "Leopard!" to the group of conspecifics nearby, the relevant Universe of Discourse will be the present situation for as long as that predator remains around. Parents will belong as constants to the Universe of Discourse of an animal for as long as he it is able to recognize them as such, that is, for a considerable longer period than a single visual scene. In short, given the more plastic logical notion of Universe of Discourse of the algebraic tradition, the very basis for Hurford's protracted problems with constants and proper nouns diminishes if not vanishes completely.

This is connected to related issues pertaining to what is the object of propositions. Hurford emphatically takes it to be physical objects as opposed to locations. This comes from his discussion of the Pylyshyn variables in the dorsal stream. Initially, attention is drawn, in the pre-attention process, towards localizations in visual space, but as soon as an object is identified at a location, it is that object which occupies the variable slot for as long as it lasts. Here, Hurford seems hardhandedly to identify "objects" with closed physical entities bounded by a surface or something similar, able to

bear properties. Most often, of course, logic examples use such mesoscopic physical objects or persons - but in logic, "object" should be taken broadly as any entity which something can be predicated about – psychologically speaking: all that which attention can be directed towards, shapes, locales, events, objects, figure/ground appearances ... Here, the Peircean distinction between Immediate and Dynamic Objects might clear up some of the confusion. When the tern chick reacts to the parental voice over the loudspeaker, it is, of course a replica of one of the Immediate Objects by means of which it usually identifies the Dynamic Object of one of his parents. Consequently, it approaches and answers this seeming Immediate Object when appearing, even if the Dynamic Object is in fact absent. Unique, individual Dynamic Objects are never encountered in all their aspects at once, but rather through one of several Immediate Objects given by the indices connecting proposition and Object. Interestingly, recent research seem to identify naturally occurring proper names in certain social species in the wild, such as the individual "whistling signature" used by bottle-nosed dolphins and recognized by conspecifics even over very long timescales.[viii]

As mentioned, Hurford's attempt to eliminate constants and proper names from proto-thought leads him to embrace an Armstrongian feature-bundle theory of animal recognition (cf. Smith 2007). Hurford's strategy in (2007) is to make everything but the variable x itself into one-place predicates, including proper names which are taken to be just one further predicate among many changing predicates. Thus, in an imaginary social species, the dominant male may be "effectively distinguished by the following set of predicates: {SLANTY-EYED, SCAR-ON-LEFT-CHEEK, TORN-RIGHT-EAR, SWEATY-SMELLING, MALE, BIG, STRUTS}" (Hurford 2007: 132).[ix] Hurford assumes this will solve the issue: "Presumably, a social animal will have such effectively distinctive bundles of features for all the members of its troop" (ibid.). Against this counts already the fact that in many species, individuals seem to be recognizable not only by a general reek of

sweat, but by their own individual chemical transpiration profile. Yet on a more principled level, this theory runs into the same problems as feature-bundle theories in ontology in general: what is "distinctive"? What is it that keeps these predicate heaps together? If no stable object/individual/constant grants that these predicates hold for one and the same entity, it is difficult to see why intermittent properties would not make the alpha male mentioned change into a completely different individual. Not even the most dominant alpha male is capable of "strutting" all of the time - as soon as he relaxes on strutting, however, he will become, following Hurford's theory, a completely different individual, and the perceiver will be unable to recognize him. Maybe he only has a *disposition* for strutting, so that it is known that he *might* strut, just like it is known that he might attack you if you approach his harem or what he is eating - but in that case dispositions should be part of the feature-bundle as well. And this raises the issue how such dispositions should be distinguished from dispositions for other intermittent behaviors (EATING, SCRATCHING HIS BALLS, HAVING A FIT OF RAGE, SLEEPING, and so on) which are not parts of the relevant feature bundle because several or many or all of the troop may resort to these behaviors once in a while (this of course, corresponds to Aristotelian essences and accidents). They are not "distinctive", Hurford might say, but how do you notice they are distinctive for an individual if you cannot keep him constant while he incarnates changing predicates? Hurford quotes Steven Pinker for the wise observation that male animals "may not care what kind of female they mate with, but they are hypersensitive to which female they mate with." (Hurford 2007: 133) - in any case it would be unwise for any primate to attempt to mate with the alpha male's preferred female partner in his presence. Still, Hurford refuses any animals are able to make Pinker's distinction between individuals and categories, unless new evidence should indicate the opposite. We have already indicated such empirical evidence, but the problem again seems logical rather than empirical. Hurford claims the problem is "uniqueness" and

rightly says uniqueness can never be established from perception alone (his version of Kant's claim that existence is not a predicate). But Peirce's Dicisign doctrine takes another lesson from Kant's famous observation. What characterizes existence is not uniqueness in qualities, but its imperative insistence here-and-now. It is this insistence, appearing for the animals in the shape of indices in its perceptual field, which forms the basis of attention (psychologically speaking) and subject status in a proto-proposition (logically speaking). So what connects the relevant feature bundles is the basic fact that they are insistently realized simultaneously in the here and now. It is the spatio-temporal coincidence of properties. After extensive discussion of his feature-bundle theory, Hurford seems, finally, also vaguely to realize the irreducibility of indexicality: "All that is left, after perceiving an object and taking in some of its properties, is the content of the information taken in, namely the properties, *plus the information that they all come from the same object*." (Hurford 2007: 155, our italics). But the sameness of that object was what was supposed to be *established* by the bundle of properties! Now, the sameness of the object is taken as that which bundles the properties in the first place. This is circular.

Here, the Peircean stance would, just like Derek Bickerton against whom Hurford argues (Hurford 2003, 286), admit both common noun predicates and constants in proto-language. Proper nouns in human language function as a device to help keeping constants constant across situations. Which animal species may have developed equivalent devices seems to be an empirical issue - but the more basic issue of having constants in certain Universes of Discourse is probably not: without constants there is no bundle to connect the features. Hurford, instead, proposes that proper nouns form a special subset of predicates. Of course, proper nouns, once they are established, may be used predicatively like everything else. Proper names depend on the basic level of "thisness". Hurford also seems to realize this much when discussing his own proto-logic formalizations with hierarchies of predicates bundled in boxes: "A

box, remember, corresponds to a logical individual variable, such as x or y. These variables have no predicative content. Pure reference, as in deictic pointing, is descriptively uninformative. The predicates inside a box can then be said to make truth claims about the object referred to" (Hurford 2007: 156-7). This formalism necessitates the representation of more than an aggregate of predicates. Something must do the bundling - a box, in turn referring to pure reference. But deictic pointing is exactly a here-and-now sign indicating the self-identical object *apart* from any of the predicates ascribed to it by the ventral stream (and assumed to be constant at least during the process of perceiving it, indicating it and having the addressee of the pointing perceive it as well). It is such pointing events (among individuals understanding the pointing gesture, cf. the discussion of by Tomasello of joint attention, see Stjernfelt forthcoming) or indexical experiences of predicate coincidence which grants an animal access to constants in its restricted Universe of Discourse.

Next problem on the list is that of polyadic predicates. The introduction of logical relations counts as one of the major progresses of modern logic, undertaken by Frege and Peirce independently. Both of them held that predicates were not only, as in the Aristotelian tradition, one-place, but could have any number of subject places. In human language, of course, most predicates have 3 or 4 places as their maximum, but there is no upper limit in principle to the possible valency of predicates in artificial languages. Hurford wants the simplest possible version of First Order Predicate Logic to account for animal behavior, and we saw how he tried to reinterpret proper names to be just a further subset of 1-place predicates. The same thing goes for polyadic predicates which he takes to be, in animals, mere sums of 1-place predicates. This, of course, is a bold claim, as many 2-place predicates seem to characterize processes very central to animal life and survival: x mates with y, x eats y, x is a mother to y, x dominates y, x and y fight, x and y groom each other, x chases y, x kills y, and so on. The elimination of such predicates is especially precarious, for they not

Comment [PB3]: recognized in it (?) by ...

only refer to processes in the animal's perceptual field - they also refer to processes many of which the animal knows from its own experience (and we have reason to believe many higher animals are able to identify the character of events including itself with the character of the same events including others, cf. mirror neurons.) Also predicates with valency higher than two may seem biologically important, maybe especially in certain higher animals: x and y fight over z; x gives y to z; x uses y to shape z; x uses y to retrieve z from w, etc.

This issue is also addressed by several of Hurford's BBS commentators. Peter F. Dominey rightly argues 1-place predicates are insufficient for event representation (291f), just like Shulan Lu and Donald R. Franceschetti (295f) argue that 1-place predicates are incapable of representing Talmy configurations like figure, motion, path, ground, invariably requiring the integration of several entities in one proposition. Hurford's way of translating such predicates into 1-predicate bundles goes back to the attention-directing process of the dorsal stream. Pre-attention addresses and screens the whole scene, and only the ensuing attention makes explicit the single, located objects of the scene, facilitating, in turn, predications to be attached to each of them. But maybe, Hurford speculates, could a scene as such be the object of predicates? Such that a "grooming scene" (his example) is recognized before each of the parcitipating groomers? This is obviously an empirical cognitive possibility in many cases (there's a fight going on - how many and who are the participants?), but it seems difficult to imagine cognition *always* should make an characterization of the scene before any of its constituents. This is not the major problem, however. The problem is rather that the animal is supposed to be able to recognize the character of the whole scene without *any* supposition about the valency of the action taking place in that scene. In some cases it might, of course, be cognitively plausible, as when seeing and hearing a remote grouplet jostling and uttering different screams and supposing this is a fighting scene. But it is really difficult to see how this could account for all cases. Seeing

your nearest conspecific eating a carrot, the following first impression is strange: "There is some eating going on, this is an alimentation scenery, but there is *not* (yet) an eater and something eaten." Or "There is some fornicating going on, but there is *not* (yet) two partners mating." The cognitive implausibility in always being able to recognize the scene type without any of the participating objects and their relation, however, is not the only problem. There is also a logical problem. For how do the animal perceive actant roles: distinguishing the eater from the eaten, as it were? There must be no 2-place predicates with different subject slots, remember, so Hurford's analysis, again, is to device two new one-place predicates: AGENT(x) and PATIENT(x). Hurford realizes the problem when he says that "... some predicates are more contextually relativized than others (...) AGENT, PATIENT, PART, and BIG, are mentally assigned to an object with much more consideration of the overall properties assigned to the scene in which they appear" (Hurford 2007: 149). But even if such consideration is taken, how do we know that the logic formalization saying "There's a BEATING event, John is AGENT, Mary is PATIENT" (Hurford's example) does not mean that John is beating into thin air while Mary is sitting passively watching? A visual scene may easily contain several objects unconnected - how do we know there is, in this case, a specific relation connecting John and Mary? Remember, we are not supposed to know that BEATING signifies a two-place relation, just that it characterizes an as yet undifferentiated scene. And remember we are not supposed to know that AGENT and PATIENT are related in any closer way than, say, BLUE and BIG; they are taken to be isolated one-slot predicates. Coupling AGENT and PATIENT, of course, would smuggle in a two-place predicate through the back door. Classic logic, both in Frege's and Peirce's variants, of course, would claim that 2- and 3-place predicates are irreducible to combinations of predicates of lower valency (but, in Peirce, not so 4-place and higher predicates which may be so reduced). Hurford's attempt to break down all predicates into conjunctions of 1-place predicates,

in any case, is less than convincing. Rather, we would assume many higher animals have access to 2-place, maybe in some cases even 3-place predicates. It should immediately be added that Peirce's logic does not - like First Order Predicate Logic in general, despite its name - have any deeper analysis of exactly predicates, including which types of relational predicates and relational roles there may be.

In Hurford's reduction, what more is left than one-place predicates? He explicitly admits he has not yet addressed the issues of negation, quantification, and inference (Hurford 2007:164), issues of some importance for cognition, but that is not quite true. In the BBS paper, the elimination of constants left Hurford with variables only, and these must, of course, be quantified: "This leaves us with quantified formulae, as in $\exists x \; [MAN(x) \; \& \; TALL(x)]$. Surely we can discount the universal quantifier $\forall$ as a term in primitive mental representations. What remains is one quantifier, which we can take to be implicitly present and to bind the variable arguments of predicates" (Hurford 2003: 267).

This idea leaves us with some riddles. If a tiger or other dangerous predator appears in the visual field, it seems a bit odd to imagine the relevant representation in perceptual logic could be "Tigers exist " without any indication of the relevant Universe of Discourse - existential quantification saying nothing about the number or the spatiotemporal location of objects predicated, rather it claims the existence of at least one case of what is affirmed. Peirce - like others after him - referred to numbers as logically a sort of quantification. So a more plausible representation would be something like: "One tiger is in my vicinity"; subitizing research (which Hurford quotes extensively) establishes that most higher animals possess the ability to subitize (not count) numbers of objects up to around four. So another such scene might give rise to the even worse proposition that "Two tigers are in my vicinity". But they would not be distinct, given Hurford's reliance on existential quantification only - here simple numerical quantification would be needed as well. The same Hurford quote

out of hand dismisses universal quantification. In the tiger example, however, the immediate action inference, in a monkey, from the perceptual judgments quoted would possibly be to flee up into a tree. But what is this inference by action based upon - probably a recognition, whether innate or acquired, that tigers are dangerous. Now, this is a universal statement: $\forall$x *[TIGER(x) -> DANGEROUS(x)]* - or, at least, a weaker quantification like *"MOSTx".* Again a conception of the universe of logical reference more modest than the Russell-Wittgensteinian reference to all of the world makes such an interpretation plausible. An innate, evolutionarily acquired fear of tigers has good reasons to be universal: if not, the danger of being eaten increases with the possibility of error (even if it might, in fact, be the case that some tigers are not dangerous). The relevant Universe of Discourse does not include zoo tigers, tame tigers, and other counterexamples which might falsify the universal. And even if the Universe of Discourse of the animal does in fact contain counterexamples, such as sick tigers, cubs or tigers not presently hungry, a strictly speaking false universal may serve the animal better than a scientifically more cautious expression with care for such exceptions. So from our point of view, we should strongly hesitate to eliminate the possibility of universal quantification from animal proto-thought. Rather, you could say its role becomes more important, the simpler the organism is: relying on instinct amounts to always reacting the same way to a given stimulus, that is quantifying universally.[x]

This is connected to the last of our logical problems with Hurford's reconstruction. The elimination of everything save 1-place predicates makes of everything an arbitrary and potentially ever-changing collection of such predicates. But would such an ontology, on the part of an animal, not prevent it from important actions related not to property predicates but to *kind* predicates - predicates like *TIGER(x)*? Hurford does not address the issue directly, and his unproblematic use of kind universals like *MEAT* or *LIZARD* or *ROCK* in his examples seems to indicate he takes them

as predicates signifying simple properties not different from *RED* or *BIG*. But kind predicates, in human languages often expressed by common nouns, are cognitively much further from immediate perception than (simple) property predicates. Lizards or Tigers may be encountered in a multitude of different ways in the visual field, in different profiles, from the front, side, or back, close or remote, with or without eye contact, night or day, and so on and so forth - not to mention their presence due to indices in other sensory modalities of the perceptual field, such as smell or hearing. Specific property bundles must be characterizing such concepts - the tiger concept (at least) consisting of STRIPED, ANIMAL, LARGE, SWIFT, DANGEROUS, CERTAIN SMELL, CERTAIN SOUNDS ... But in such kind property bundles, universal quantification lies immediately: the bundle claims tigers in general have all of these properties, which is why DANGER can be deduced from the TIGER concept and abduced from some of its other components.

A final issue of which Hurford is well aware is that it does not suffice to have two brain circuits responsible for the analyses of Subject and Predicate respectively. The proposition is a whole unites the two in a characteristic way, the understanding of which has not yet been exhausted. In order to grasp this aspect of the proposition, it is necessary to look at 1) the interaction between the two streams, and 2) the ensuing action, either in terms of outward activity or in order of renewed proposition activity. Bruce Bridgeman says in the BBS comments: "Anatomical connections between dorsal & ventral streams do not contradict the separability of their functions, any more than communication between two people contradicts their distinctness. Communication between the two streams is needed to initiate action (usually a cognitive-system function), to monitor progress in the execution of the action, and to modify goals of actions." (Hurford 2003, 287).

Here, Bridgeman points to another issue where the Peircean pragmatist conception of logic differs from Hurford's reliance upon Frege: the connection between logic and action which is also

addressed by MacNeilage and Barbara Davis (296f). To Peirce, the formation of habits is the general aim of reasoning, be it action habits or thought habits.[xi] This is the same reason why Bridgeman addresses the important point of the action taking place as a result of the proposition shaped by the ventral-dorsal pincer movement: "Plans for action exist separate from the sensory or motor worlds, and their steps must be executed in a particular order to be effective. Grammar may have appropriated an existing capability for planning of action sequences to the planning of communicatory sequences (Bridgeman, 1992). Language, then, is a new capability built mostly of old parts, but the parts originate in motor planning, not in visual coding."

Bridgeman's idea that action planning could be important for the linearization of grammar (there's no explicit order implied by the ventral-dorsal S-P processing) as well as for the reasoning sequence linking chains of propositions is promising. In simpler animals we may surmise much establishing of propositional *Umwelt* knowledge feeds directly into action, forming immediate feedback on the truth value of the proposition implied.

We have entered so deeply into the discussion of Hurford's application of logic in his theory of the proto-thought of animals because we recognize the bold, interdisciplinary character of his hypothesis and the wide-ranging importance it may hold. Logic is not an early piece of sketchy psychology only - rather, it addresses some of the prerequisites of how any cognitive system must be constructed in order to address *Umwelt* facts. And therefore, it becomes of seminal interest to chart how the possibilities for instantiating logic evolved biologically. Here, the virtues of Hurford's daring hypothesis emerge clearer when interpreted in the framework of Dicisigns, just as some of the logical shortcomings of the way he develops the hypothesis vanish or may be corrected, to some degree, in the Peircean picture of logic.

First of all, of course, this is evident from Peirce's non-linguistic take on logic which easily lends itself to exactly an

attempt to chart the logic inherent in pre-human, pre-linguistic proto-thought. Furthermore, Peirce's logic, due to the functional definition of the Dicisign, does not need prerequisites like an explicit "propositional stance" taken by a conscious being. Signs satisfying the basic functional requirements will be categorized as propositions or proto-propositions no matter whether accompanying phenomena of consciousness can be detected (which, of course, is difficult or impossible in most of non-human biology). This also opens the door to extending the Dicisign doctrine much further into biology than Hurford's primary focus on primates.[xii]

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[i] Schneider (1969) proposed two visual systems for localization and identification, respectively. The classic paper establishing the ventral-dorsal split is Ungerleider and Mishkin (1982) which proposed the *What/Where* description of the two streams, taken to process spatial location and object qualities respectively. Goodale and Milner (1992) and Milner and Goodale (1995) proposed the alternative *What/How* distinction and claimed the streams to be functionally different rather than addressing different contents; thus both streams seem to process shape and spatial information but with different functional aims. Norman (2002, 73) attempted to reconciliate approaches: " A dual-process approach to visual perception emerges from this analysis, with the ecological-dorsal process transpiring mainly without conscious awareness, while the constructivist-ventral process is normally conscious" and summed up the characteristics of the two streams in the following diagram:

FACTOR	VENTRAL SYSTEM	DORSAL SYSTEM

Function	Recognition/identification	Visually guided behaviour
Sensitivity	High spatial frequencies - details	High temporal frequencies - motion
Memory	Long term stored representations	Only very short-term storage
Speed	Relatively slow	Relatively fast
Consciousness	Typically high	Typically low
Frame of reference	Allocentric or object-centered	Egocentric or viewer-centered
Visual input	Mainly foveal or parafoveal	Across retina
Monocular vision	Generally reasonably small effects	Often large effects e.g. motion parallax

Livingstone and Hubel (1987) takes the division of processing back to early visual processing in the Thalamus where magnocellular and parvocellular areas seem to process location/movement and color/shape, respectively, informations ultimately deriving from rods and cones in the retina. This speaks for the claim that the split already can be found as a functional division of labor in the retina.

[ii] Peirce's Dicisign doctrine claims propositions are double signs simultaneously indicating and describing their objects - see my "Natural Propositions. The Actuality of Peirce's Doctrine of Dicisigns" (forthcoming)

[iii] The Adaption to Rationality hypothesis finds a clear expression here: ""But the views of all the leading schools of Logic of the present day, of which there are three or four, are all decidedly opposed to those of the present writer. That common tendency of them which he most of all opposes is that toward regarding human conscioiusness as the author of rationality, instead of as more or less conforming to rationality. Even if we can find no better definition of rationality than that it is that character of arguments to which experience and reflexion would tend indefinitely to make human approval conform, there still remains a world-wide difference between that idea and the opinion just mentioned. But the thinkers of our day seem to regard the distinction between being the product of the human mind and being that to which the human mind <u>would</u> approximate to thinking if sufficiently influenced by experience and reflection, as a distinction of altogether secondary importance, and hardly worth notice; while to the writer, no distinction appears more momentous than that between "is" and

"would be"." (Ms. 640. Essays on Meaning. Preface (Meaning Preface) 23 Oct 1909)

[iv] The claim that the basic function of perception is to give true representations of environment features seminal for action immediately implies that perception may sometimes fail - cf. for instance visual illusions.

[v] Hurford is not the only scholar interpreting the Ventral-Dorsal split logically. Hintikka and Symons (2007) interpret the split as realizing two different modi of identification of objects earlier analyzed by Hintikka: public, or object-centered vs. perspectival, or subject-centered identification - examplified in "Jane sees b" vs. "Jane sees who b is". To Hintikka and Symons, this analysis calls for two different types of quantifiers referring to the types of identification. The two do not, unlike Hurford, attempt to eliminate constants (b); the cross-identification of b across the two modes may make possible propositions of the shape *Predicate (b)* describing who it is Jane sees b as.

[vi] "In every discourse, whether of the mind conversing with its own thoughts, or of the individual in his intercourse with others, there is an assumed or expressed limit within which the subjects of its operation are confined. The most unfettered discourse is that in which the words we use are understood in the widest possible application, and for them the limits of discourse are co-extensive with those of the universe itself. But more usually we confine ourselves to a less spacious field. (…) Now, whatever may be the extent of the field within which all objects of our discourse are found, that field may properly be termed the universe of discourse." (*The Laws of Thought*, p. 42)

[vii] From "Universe," Baldwin (ed.) *Dictionary of Philosophy and Psychology,* vol. 2, p.742, by Peirce and C. Ladd-Franklin.

[viii] Cf. King and Janik (2013); Bruck (2013).

[ix] Such a feature bundle would not even be able to grant individual reference in the whole world of possibilities. Hurford's own speculative "identical twin" thought experiment proves this. So the important thing is to establish a restricted Universe of Discourse where such a bundle could, in fact, be unique.

[x] Hurford's idea seems to rest upon the empiricist presupposition that animal minds are blank slates which build up all content from individual, particular perceptions. But evolutionarily, such perceptions seem to be a late and sophisticated capacity. Simpler animals seem to depend highly on quasi-automatic perception-action links - logically equivalent rather to instantiations of universally quantified propositions: "For all x, if x is edible, eat x".

[xi] Central to the pragmatist doctrine is the claim that the conclusions of inferences are *action habits* rather than psychic representations. Some of those habits, of course, may be mental, even conscious, but that is not their defining property:
"The general form of our inquirer's activity will be as before experimental, though the experiments will be much more intelligent and purposive than they were before this pertinent ide had been suggested.

It is evident that when the problem is solved, the researcher will have acquired a new habit to which the various concepts, or general mental signs, that have arisen and been found valuable, are merely adjuvant.

Meantime, the psychological assumption originally made is in great measure eliminated by the consideration that habit [is] by no means exclusively mental. Some plants take habits; and so do some things purely inorganic. The observed laws of habit follow necessarily from a definition of habit which takes no notice of consciousness. Thus the facts that great numbers of individuals which die and are replaced by reproduction is favourable to a marked prominence of habit, and that highly complex organisms of which multitudes of parts exercise interchangeable functions are so, follow from such a definition.

Nevertheless, I am far from holding consciousness to be an "epiphenomenon", though the doctrine that it is so has aided the development of science. To my apprehension, the function of consciousness is to render self-control possible and efficient. For according to such analysis as I can make the true definition of consciousness is connection with an internal world; and the first impressions of sense are not conscious, but only their modified reproductions in the internal world.

I do not deny that a concept, or general mental sign, may be a logical interpretant; only, it cannot be the ultimate logical interpretant, precisely because, being a sign, it has itself a logical interpretant. It partakes somewhat of the nature of a verbal definition, and is very inferior to the living definition that grows up in the habit. Consequently, the most perfect account we can give of a concept will consist in a description of the habit that it will produce; and how otherwise can a habit be described than by a general statement of the kind of action it will give rise to under described circumstances?" (Ms. 318, 1907, p. 74 of one version, 10-12).
[xii] An attempt pursued further in Stjernfelt (forthcoming).