

Definition-1: Noémon species \mathcal{E} is a species whose individuals:

- a) Possess one or more sensory systems.
- b) Possess one or more motor systems.
- c) Possess the ability of thinking.
- d) Are able to communicate with other individuals of their own species.
- e) Possess the ability of creating representations.

Definition-2: For an animal \mathcal{A} , I call neural formation, N , a structure of *interacting* sub-cellular components across nerve cells able to influence the survival or reproduction of \mathcal{A} .

Definition-3: For an animal with nerve tissue, \mathcal{A} , a neural formation is meaningful (symbol N_m), if and only if it is an N that influences the attention of that \mathcal{A} .

Definition-4: I will use the symbol S_c to stand for a stimulus within its context.ⁱ

Definition-5: The meaning of a novel S_c , for the human \mathcal{H} at time t , is whatever N_m is created by the interaction of S_c and \mathcal{H} at time t .

Definition-6: The meaning of a previously encountered S_c , for the human \mathcal{H} , at time t is the *prevailed* N_p of \mathcal{N}_p .

Definition-7: Skepseis are structures of neural formations that may or may not involve N_m , although normally they do.

Definition-8: Let 1N_m be the first neural formation *created* by the specific triad (S_{c1} , \mathcal{H} , t_1). Then the system of all jN_m (j a natural number) of human \mathcal{H} that have been created by time t later than t_1 I call it a concept of \mathcal{H} up to t and I symbolize it by ${}^\varepsilon\mathcal{N}_m$.

Definition-9: σ is a thought of human \mathcal{H} if and only if σ is a flexible and not necessarily permanent structure of concepts and/or N_m (i.e., meaningful neural formations, as per definition-3).

Definition-10: Belief =_{def} A structure of neural formations and meaningful neural formations on the basis of which one is prepared to act, argue, or live by.ⁱⁱ

Definition-11: Thinking, \mathcal{T} , is the interaction of meanings, or concepts, or thoughts, or beliefs, or of any combinations of them.ⁱⁱⁱ

Definition-12: A human \mathcal{H}_1 has communicated with \mathcal{H}_2 on a topic T if, and only if:

- a) \mathcal{H}_1 has understood T -symbol: $U(\mathcal{H}_1, T)$;
- b) \mathcal{H}_2 has understood T -symbol: $U(\mathcal{H}_2, T)$;
- c) $U(\mathcal{H}_1, T)$ is presentable to and understood by \mathcal{H}_2 ; and
- d) $U(\mathcal{H}_2, T)$ is presentable to and understood by \mathcal{H}_1 .

Definition-13: A human \mathcal{H} has understood something, S , if and only if, \mathcal{H} can think of S in terms of a system of human primitives (symbol $\Pi_{\mathcal{H}}$).

Definition-14: π is a primitive of/for \mathcal{H} if and only if the meaning of π is immediate for \mathcal{H} .

Definition-15: For a human \mathcal{H} , an external representation of a situation \mathcal{K} is an artificial construction \mathcal{A} characterised by the properties:

- a) \mathcal{A} is a simplification of \mathcal{K} ; and
- b) \mathcal{A} has been designed or constructed by \mathcal{H} in order to preserve the essential characteristics of \mathcal{K} .^{iv}

Definition-16: For a human \mathcal{H} , a neural representation of a situation \mathcal{K} is an \mathcal{N}_m structure such that:

- a) It is a simplification of \mathcal{K} ; and
- b) It tends to preserve the essential characteristics of \mathcal{K} .

Open Issues

Of the many remaining open issues the following seem to me among the most important. First, there is the problem of the appropriate formulation of a ‘*mental phenomenon*’. If the theory proposed here is accepted a good number of accepted distinctions will cease to exist and a significant number of new problems will appear. Among the latter probably the most important is the task of understanding more thoroughly and deeply the extremely complex interactions between the social and biological aspects of humans as well as the much more difficult tasks of the relations among human communities and the emerging new era of the artificial. Among the former, it seems that the mind-body problem will be the first that will have to be abandoned with a domino-effect ramifications.

Second, there is the issue of the suitability of our current tools for developing a theory of individuals as parts of noémona species. It seems to me that most current mathematics is inadequate for such an endeavour. The precision of equations and computational systems is at odds with the precise vagueness of the mammalian nervous system. To describe the \mathcal{M} and $\Pi_{\mathcal{M}}$ structures, as well as the systems of fundamental processes and associated loops identified earlier, ‘the mathematics of thinking and communication’ is required. This is a branch of knowledge humans have not yet developed. It is always good to be kept in brain that even order is not a prerequisite for phenomena like emotion. As James (1890, Vol.2, p. 146) factually remarked: “Different feelings may coexist in us without assuming any particular spatial order.” I would therefore urge that for the foreseeable future the methodology outlined in the introduction is to be preferred to the usual mathematical tools employed. Development of a fully-fledged language-based definitional system compatible with as many field-wide empirical data and regularities as possible seems the best way to proceed in the present state of the art. This may be one way towards ‘the mathematics of thinking and communication’. Assuming that such mathematics is possible.

Third, there is a need to try to identify invariant laws for cognitive science. Simon (1990) has elevated this objective to the status of the fundamental goal of science and has suggested two laws of qualitative structure and four quantitative findings as invariants. Newell (1990) strongly believes that the computer hierarchy is an invariant law. Nevertheless, the issue is far from straightforward. Relations to universals and classification are just two of these.^v

Fourth, cognitive science needs a minimum vocabulary to serve as its descriptive base. The one proposed in the previous section may be taken as a first step. An appropriate \mathfrak{V} must be able to account for at least the following areas of an augmented cognitive science: knowledge, consciousness, emotion, culture, motivation, ethical values, and beauty. It appears that consciousness and knowledge may be explainable in terms of the theory proposed here. To demonstrate such a hunch and modify or not \mathfrak{V} is the major task I intend to address next.

Fifth, mental neuroscience needs to map observed types of NS complexity to fundamental animal abilities and semantic structures (\mathcal{M}). In speculative mode, I posit several such types in Table 3. Empirical evidence may collapse/expand some of the posited types. Their rough correspondence to fundamental animal abilities and loops may help the design of neuroscientific experiments.

Finally, as a community, we should pay careful consideration in the emergence of, and the consequences brought by, the era of the artificial. Definitely, it is not an exclusively cognitive science issue; not even of an augmented cognitive

science. It is also a political and most importantly an ethical issue. All the more so, that we need to pay very careful attention to it.

Table 3. Rough mapping of key animal abilities to Eras and posited nervous systems.

Posited types of Nervous Systems (NS)	Era
Simplest NS (i.e., structures of \mathcal{N}_m)	Exclusively natural mind.
NS incorporating meanings	
NS incorporating thinking	
NS incorporating memories	
NS originating and externalizing actions	
NS incorporating concepts	
NS incorporating representations	Artificially natural mind.
NS incorporating thoughts	
NS originating and externalizing representations	
NS enabling writing	
ACER = Ability to create external representations = $\text{ext}\mathcal{R}_H$	

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ⁱ Subsequent definitions are in terms of human animals. Generalisations to non-human animals and machines are straightforward.

ⁱⁱ This is a minimalist definition of belief. It could have been stated in a way that it explicitly included any combination of concepts, thoughts and skepseis. Since all three of the latter are defined in terms of N and/or N_m , the minimalist definition was thought to be more appropriate.

ⁱⁱⁱ Clearly, the proposed theory of thinking is in sharp contrast to both major approaches, namely the standard psychological view of concepts (e.g., initially Fodor 1975; recently Margolis & Lawrence 2007) and the propositional (equivalently, Fregean or semantic) view (e.g., Peacocke 1992).

^{iv} This definition is in accordance with both Aristotle's (4th BCE*1984) views on poetry and drama as human endeavours to mimic (i.e., re-present) *the essence* of human actions and the standard cognitive science view stated earlier.

^v For a recent philosophical discussion see Silverberg (2003).