TEMPORAL QUANTITATIVE ASPECTS OF CREATIVITY

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Abstract. In this paper we argue that complex qualitative phenomena such as creativity can and should be investigated from a quantitative viewpoint and, in particular, within the framework of a time-constrained model of memory.

1. Introduction

In the glossary of his book *The Society of Mind*, Marvin Minsky (1986, p.327) offers the following 'definition' for the word **creativity**:

> "The myth that the production of novel ideas, artistic or otherwise, comes from some distinctive form of thought".

In the spirit of the rest of the book, he adds:

> "I don't believe there is much difference between normal and 'creative' thought. Right now, if asked which seems the more mysterious, I'd have to say the ordinary kind." (*Ibid.*, p.80)

And, in order to investigate thought and cognition in general, Minsky observes that:

> "To explain the mind, we have to show how minds are built from mindless stuff, from parts that are much smaller and simpler than anything we'd consider smart." (*Ibid.*, p.18)

The latter remark suggests a dichotomy between the *quantitative* ('mindless', non-semantic) aspects of cognition and the *qualitative* ones. Within the framework set forth by this distinction, we focus in this paper, on the quantitative aspects of creativity and, more precisely, investigate the role that *processing time* may play during creation.

The fundamental postulate of our work is the assumption that *time-constrained memory processes* underlie cognition in most of its forms. This hypothesis proceeds not only from the biological constraint that emphasizes the short response times of humans for hard cognitive tasks (Feldman, 1984), but also from psychological evidence suggesting that humans feel a determinative pressure to understand quickly (*e.g.*, Márkus, 1983, for inference; Norris, 1986, for word sense disambiguation). In essence, we 'ground' mind into quantitative (purely mechanical) processes that implement a memory architecture. More qualitative processes (*e.g.*, linguistic disambiguation, see Corriveau, 1987 and 1991b) are to be explained in terms of this model of memory. In other words, much like Minsky's use of *K-lines* (1980) and *time blinking* (1986, p.240), we suggest that complex cognitive tasks be specified in terms of quantitative memory processes.

An in-depth discussion of this hypothesis lies beyond the scope of the present paper (see Corriveau, 1991a and 1991c for further details). Instead, we want to specifically look here at the role of processing time (hereafter simply time) with respect to creativity. In the next section, we will briefly comment on existing research on creativity. Then, in section 3, we will focus on some of the quantitative facets of creativity.

2. Creativity Revisited

As a psychological phenomenon, creativity, be it in painting, music, or literature, has often been regarded as idiosyncratic, omnipresent and somewhat 'mysterious'. Koestler (1975), for example, presents a theory of creativity resting on the key concept of *bisociation*, which is defined as the simultaneous activation and interaction of two previously unconnected concepts. More pragmatic, if not computationally-oriented, accounts of creativity have also been proposed. In particular, Hofstadter (1985, p.250) argues that the crux of creativity consists in making variations on a theme, and that "the crazy and unexpected associations that allow creative insights to pop seemingly out of nowhere may well be consequences of a chemistry of concepts with its own special types of 'bonds' that emerge out of an underlying 'neuron mechanics'." On the one hand, bisociation emphasizes the coming-together of *two* concepts: "In Koestler's view, something new can happen when two concepts 'collide' and fuse; something not present in the concept themselves." (*Ibid.*). On the other hand, Hofstadter's argument centers around the idea of the internal structure of *one* concept: "the way that concepts can bond together and form conceptual molecules...is a consequence of their internal structure." (*Ibid.*).

Despite having been emphasized by several authors (*e.g.*, Di Pietro, 1976; Guilbert, 1975), the role of creativity with respect to language (comprehension and generation) has been generally ignored in computational accounts of these problems. However, the conception of creativity that Hofstadter favors, which is based on the divisibility of concepts into subconceptuals elements, has come to dominate work on computational accounts of metaphor understanding (*e.g.*, Gentner, 1986; Indurkya, 1992) and analogy modeling (*e.g.*, Gentner, 1989). In both cases, the creative facet of the problem is explained in terms of rules to construct a mapping between the subcomponents of two mental entities. Such an approach is problematic (see Plantinga, 1989) in that it typically postulates *a priori* a specialized processing strategy for the problem at hand. In other words, researchers typically hypothesize that metaphors and analogies (much like 'figurative' meaning and 'ill-formed' input) somehow trigger their own rules of understanding. Such an assumption clearly goes against Minsky's (1986) warning that there is no solid evidence just yet to grant the existence of significant processing differences between 'normal' and creative thought. Furthermore, as Wiener (1982) remarks, there are currently no commonly-accepted theories of creativity.

It is not our intention to review existing work on creativity, but rather to emphasize two points.

First, we remark that current theories of creativity are essentially qualitative, that is conceptual: creativity is often taken to consist in the bonding of two (or more) ideas or concepts. If there is still disagreement on the nature of the bonding process, it is however generally accepted that this process links two mental entities. Consequently, most researchers look for *the rules* of creativity, much like designers of natural langugage understanding systems search for *the correct* set of rules to produce the single determinate meaning of a sentence or text. But explaining a mental activity, namely creativity, only in terms of mental entities (rules), leads not only to a certain ad hocness of the proposed systems[1] but also to the sort of circular definition Minsky (1986) warns us against: cognition must be explained in terms of non-conceptual entities and processes.

Second, we stress that quantitative facets of creativity are often present but downplayed in existing theories. Consider Koestler's notion of bisociation. A key requirement of this idea is the simultaneous activation of two concepts. Such simultaneity can be defined not in terms of concepts, but rather with respect to memory, as we will explain in the next section. As for Hofstadter, he himself speaks of the neuron mechanics underlying creativity and, in particular, highlights their quantum-mechanical 'ephemeral' nature. We will argue below that this 'elusiveness' of the created bonds directly pertains to memory and time: new bonds are short-lived memory entities that must be 'learned' (*i.e.*, made recognizable for later retrieval) or forgotten.

Given that existing theories often include some quantitative facets and that considering these facets is necessary, we will now briefly suggest where time may play a role in creativity, and in particular, in *uncontrolled* creativity (hereafter simply creativity), that is, in creative production that does not result from the conscious application of a set of generative techniques (such as in Bach's fugues, as discussed in Hofstadter's book).

3. Time-constrained Recognizable Juxtaposition

We propose that creativity depends, in part, on:

1) the construction of a new memory link, a K-line in Minsky's terminology (1980, 1986), between two (or more) simultaneously activated features[2] in memory and

2) the detection of this new K-line within a short interval of time by the learning agency[3].

In other words, from a quantitative viewpoint, creativity rests on a process we call the *time-constrained recognizable juxtaposition* of features in memory. Let us elaborate.

First, we take cognitive tasks to occur with respect to a *context*, that is, with respect to a set of currently activated features. The notion of contextualized cognitive tasks is well accepted in psychology but has been typically downplayed in computational cognitive models (which avoid the intricacies of research on implicit memory (see Lewandowsky *et al*, 1989)). The role of context appears to be particularly relevant to creativity. For example, Minsky (1986, p.85) remarks that "we make our new ideas by merging parts of older ones---and that means keeping more than one idea in mind at once". In our model of **time-constrained memory** (see Corriveau, 1991a), context is intimately tied with time: Memory consists of three temporal partitions, namely, working memory (WM), short-term memory (STM) and long-term memory (LTM). Features constantly decay[4]

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[1] Consider a specific example. In the very rationalist (i.e., cartesian) society of Louis the Fourteenth of France, the Académie de Peinture ruled all of painting. In particular, Lebrun had edicted rules that defined and effectively constrained creativity long after his death. For example, one reads in l'Encyclopédie "hate and jealousy. This passion causes the forehead to be wrinkled, the eyebrows low and frowning, the eye sparkling, the pupil half-hidden by the eyebrows..., the mouth closed so that teeths can be seen to be clenched together...etc." (my translation). Though rejected by some marginal painters, such rules were not abandoned before the end of the Ninteenth century!

[2] We will use the more familiar and general term 'feature' rather than the word 'agent', which is specific to Minsky's model of memory (1986, chapter 8). A feature is meant to correspond to an agent or set of agents, or to a (possibly partial) mental state. Also, for clarity and conciseness, we will not discuss here the specification of our proposal in terms of partial mental states and other components of Minsky's model of memory. The reader unfamilar with Minsky's work should simply think of a feature as a memory entity (be it symbolic, conceptual or subsymbolic) that has the property of being active or idle at a given point in time.

[3] We hold a great debt to Minsky not only for the conceptual framework of his 1986 book, but also for his terminology, which we use without properly reintroducing due to the space limitations of this paper.

[4] More precisely, when retrieved from long-term memory, a feature is placed in working memory and is given a certain initial level of activation (*i.e.*, energy). The feature gradually (read, exponentially) looses this energy as time elapses. A feature in WM with insufficient activation is moved to STM. A feature in STM with insufficient energy reverts to being dormant (*i.e.*, non-retrieved) by 'moving back' to LTM.

and 'move' between the memory partitions[5], which control the access to and the use of these features by other features. Intuitively, the context is the set of features that are readily accessible (*i.e.*, in working or short-term memory) at a given point in time. We require that the features to be creatively combined, that is to be juxtaposed, be members of this constantly-changing context simultaneously. In other words, only features that coexist (*i.e.*, exist simultaneously) in the context can potentially be juxtaposed.

Given some simultaneous features in context, a new K-line (*i.e.*, memory link) can be obtained if and only if some sort of merging can indeed occur between these features. A multitude of features coexist in the context at any given point in time, but not all can be or are merged. We can think of the creation of a K-line as a process that constructs some sort of bond between a set of features. In essence, the K-line creates a set of features to be reactivated as a whole, that is, a set of coretrievable features. Because a feature can denote even a complex semantic entity, we include in this bonding process not only the combination of subsymbolic features, but also semantic creativity (such as linking concepts to obtain new words and metaphors, applying a rule to a novel set of arguments, applying a question to a theory, *etc.*). It is not clear whether the creation of a K-line requires knowledge (the constructivist hypothesis) or is instantaneous (the Gestalt theory) (see Wiener, 1982, p.109). However, from a quantitative viewpoint, both the nature of the features merged by the new K-line and the possibility of using knowledge during this 'bonding' process are irrelevant. What matters are the <u>mechanics</u> of the creation of a K-line. And, from our standpoint, what matters is that the creation of a new K-line is taken to be a time-constrained process: the actual merging of two or more features into a new K-line occurs only if the latter can be constructed within the short interval of time defined by the simultaneity in context of the features to bond. More precisely, the juxtaposition *per se*, that is, the construction of a new K-line, must occur while the features to merge are in context. Otherwise, the juxtaposition could fail due to the absence (*i.e.*, non-accessibility within a short amount of time) of one of these features. Hence, quantitatively speaking, creativity involves the time-constrained juxtaposition (*i.e.*, bonding) of features in a new K-line. A model of creativity would therefore, in our opinion, gain in being rooted in a model of memory that captures time-constrained juxtaposition[6].

Second, once a new K-line has been constructed, it may be readily merged with other features in context in order to create yet another new K-line. In other words, the juxtaposition process can be recursive. But a K-line is merely a feature, that is, a memory entity *per se*: it is created in context, starts decaying, and eventually can be either 'transferred' to long-term memory or forgotten. By definition, when a new K-line is constructed, it is not immediately recognizable (*i.e.*, recallable or retirevable): it must be 'learnt' in order to become recallable. Because they are merged with other features before they are learnt, some created K-lines will not be recallable by themselves, but only as part of larger (recursively) created features. And some K-lines will be simply lost (*i.e.*, forgotten and moved out of memory before they are learnt). But some new K-lines do become recallable. We suggest that this learning process is also time-constrained. More precisely, if we view mind as a society of agencies (see Minsky, 1986), then we must consider, at a quantitative level, the communication delays to 'reach' these agencies. Because of these delays, we hypothesize that the detection of a new K-line by the learning agency[7] occurs within the short time interval defined by the existence of this new K-line in context. In other words, once out of context, a feature requires too much time to communicate with any agency and thus cannot be memorized and made into a recognizable whole: its 'learnability' spans the short interval of time it is in context. Similarly, a new K-line's ability to be 'picked up' by the consciousness agency is also, for the same reasons, time-constrained. And thus, the 'elusiveness' (see section 2) of created ideas partly depends on quantatitive time-constrained processes.

4. Conclusion

In the end, we are back to our initial proposal, namely, that complex qualitative phenomena such as creativity can and should be investigated from a quantitative viewpoint and, in particular, within the context of a time-constrained model of memory. In order to model the mechanics of creativity, we emphasize the notions of a quantitatively-defined context (resting on the temporal partitioning of memory) and of communication delays between the 'agents' of the mind, that is, between the activated memory entities of a quantitative cognitive architecture. We suggest that more qualitative accounts of creativity, such as Hofstadter's (1985) notion of variation on a theme, as well as traditional explanatory tools for creativity (*e.g.*, analogy), be grounded in such a model of memory, that is, be expressed in terms of K-lines, agencies, time-constrained processes, *etc.*

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[5] Movement depends not only on activation levels but also on the capacity of each memory partition.

[6] A prototype of time-constrained memory has been built in Smalltalk-80 [Goldberg, 1984; Smalltalk-80 is a trademark of ParcPlace] and is being ported to the object-oriented concurrent programming language ABCL/1 (Yonezawa *et al.*, 1990). The Smalltalk model has been used primarily to investigate the role of time during linguistic disambiguation (Corriveau, 1991b). The port to a concurrent language stems from the importance we have observed during our experiments to accurately model parallelism and simultaneity.

[7] The learning agency is responsible for *stabilizing* a memory entity so that it can be eventually reactivated *by itself*, that is, as a whole (rather than only as part of something else). Only entities processed by the learning agency are retrievable *per se*. Also, this learning agency is distinct and independent of what Minsky (1986) calls the consciousness agency.

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