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A modern perspective on creative cognition by Stuart E. Dreyfus

Unsurprisingly, the brain process leading to human creativity has long been the subject of study and speculation[i], not only because creative thought is both awesome and often of great value but also because an understanding of the production of this uniquely human phenomenon portends the possibility of testing to assess an individual's creative potential and hopefully of devising methods of enhancing creative ability through training. This paper posits that to exploit these possibilities requires an overarching, but not necessarily detailed, understanding of the operating principles of the human mind/brain system, and that modern technologies of neuroscientific research are beginning to make this possible.

The typical creative process varies, not only with the domain of activity (for example, artistic creativity differs from that in science, which differs, in turn, from that in business and industry), but also with the nature of the particular situation in the domain. For example, a business executive's creative positioning of a company for success in the long-term future differs significantly from a manager's creative problem solving during the conduct of an on-going endeavor. Although what follows focuses only on business and industry, and we specialize to a certain type of situation in that domain, namely, complex construction project direction, we believe that our study reveals a way of thinking about creativity that would be appropriate with only minor modifications to the investigation of creativity in many situations in most domains. Our reason for going through a particular example is that the special abilities involved in each type of step in the hypothetical process outlined below could then themselves become the subject of academic creativity research directed toward issues of training and evaluation. Unconstrained research on creativity in general seems too unfocussed to be useful.

One general observation that seems applicable to almost all real-world domains is that, contrary to the *a ha* experience evoked by the solution of a puzzle with no obvious solution but for which a solution is known to exist, creativity is rarely, if ever, a sudden bolt from the blue. It requires an almost visceral desire to deal imaginatively with a perceived problematic situation, the willingness to tolerate possible failure as one searches for a solution, and

a passionate, sometimes conscious and at other times subconscious, involvement in the overall activity. In short, it is generally hard work, accompanied by elation when progress appears at hand and tolerance of the pain when it does not[ii].

Motivated by current neuroscientific research, this paper distinguishes two dimensions that together characterize the nature of each step during a typical real-world creative process. One is the *mode of thought*, the other is the *focus of thought*. The former characterizes how the brain is processing information, the latter, the subject of that processing. Each dimension can take on two distinct values, so there are four possible combinations of mode and focus. A complete creative effort can then be described as a dynamical movement among these four available options.

Calling themselves behavioral or cognitive neuroscientists, a large number of researchers currently use data obtained from such very modern sources as event-related functional magnetic resonance imaging (fMRI) of the brains of humans actually acquiring and performing simple cognitive, albeit uncreative, skills. Others use somewhat more conventional brain activity location indicators as the electroencephalograph (EEG). An even more venerable source of information has been the observation of skill or behavioral changes, usually deficits, of people suffering known brain-area lesions or diseases. While brain areas so identified were once seen as the obvious source of such behaviors, the modern network paradigm of neuroscience holds that skills or behaviors require the interaction of an ensemble of brain areas and that only one element of that ensemble has thus been identified.

Since lower animals also learn and execute behavioral skills, their brain processes are also studied, usually by invasive procedures not allowed on healthy humans such as implanted probes sensing electrical activity in individual neurons or arrays of neurons.

These methodologies have revealed a picture of two separate brain systems in humans. One is shared with all lower animals capable of learning adaptive behaviors through real-world experience. This system is located, not mainly in the celebrated cerebral cortex with its convoluted grey matter, but rather in subcortical regions largely lying below the cerebral cortex, although certain cerebral cortex areas are also involved. Learning and executing environmentally adaptive behaviors involves various interacting networks of neurons. During learning, events trigger synaptic changes that modify the association of outputs with inputs produced by component neural networks. The outputs thus produced become inputs to other similarly trained neural networks until ultimately a certain net's output triggers

physical behavior or, probably almost exclusively for humans, thoughts. The performance of this system, once trained, is variously called in neuroscientific and cognitive psychological studies implicit, automatic, procedural, habitual, or, in less technical literature, intuitive. Such behavior is experienced by humans as fast, relatively effortless, and generally appropriate, with no conscious awareness of the method of its production. An experienced automobile driver navigating a familiar city and encountering no novel situations is a typical example of intuitive expertise[iii]. Since lower animals depend exclusively on implicit behavior, it is not surprising that there is no evidence of anything going on in the implicit human brain as its neural networks map inputs into outputs that can reasonably be described as planning or reasoning. Of course, the input that starts this whole mapping process can, for humans, be neural activity admitting a conceptual interpretation, as can the output. An ongoing conversation between friends is normally intuitive in that it is effortless and perfectly appropriate, unlike a conversation with a stranger where one might employ conscious effort to keep the conversation going satisfactorily.

An effortful, conscious brain system uses its own largely independent set of interacting areas mainly located in the cerebral cortex. It is called mind in everyday discourse, and explicit, controlled or analytical processor by behavioral neuroscientists and cognitive psychologists. This system, almost exclusively the domain of human beings, is active in novel situations and produces such phenomena as reasoning, planning, and choice among alternative behaviors.[iv] The mind is the seat of consciousness and allows introspection and therefore presents itself to us as our essence. Since, unlike for the implicit brain, we are generally aware of our thinking process, the neural basis of its functioning needn't concern us here. Close examination of the experience of our mental processes, however, reveals that they almost always depend on intuition to determine toward what one should plan, about what one should reason and among what set of behaviors one should choose.

It appears that the intuitive brain can perform without analysis, as it certainly does in most lower animals, while the analytical brain needs help from the intuitive one to do its job. The analytical brain can, however, prevent the intuitive brain from undertaking a task by judging the situation to be too novel to merely trust the synaptic connections that have been created through repeated real-world experiences of successes and failure.

We turn now to the second dimension that seems essential to understanding the creative process, the focus of thought. Based on phenomenological insight supported by neuroscientific evidence, one can profitably distinguish between two different focuses. The first is one's

perspective, sometimes called framing or cognitive control. This produces the ability to behave in accordance with the context, goal or rule[v]. Perspective determines what stands out as salient in a situation, what is on the fringe of awareness, and what is ignored. In a normal situation, perspective, and the circumstances that will change it to a different perspective, is learned by the intuitive brain based on successful experiences. Perspective in novel situations must be *chosen* by the analytical mind[vi].

The second possible focus of thought is the information seen from a perspective. Can information not immediately available to one be obtained from memory, or the minds of others, or a research effort or elsewhere that will, perhaps, when included in one's thoughts, lead to a creative response? While perspective is a way of organizing what is before one, the second activity involves changing what is organized. In the neuroscience literature concerning implicit learning and behavior, what is before one is sometimes called "the bottom-up stimuli" while perspective is sometimes referred to as the "top-down gating of the stimuli"[vii]. We shall use "perspective" and "stimuli" to refer to these two possible focuses of thought. While in the experimental neuroscientific literature the stimuli are generally provided by the sense organs, in the conceptual world they include facts, concepts, theories etc. as well as what is taken in by the five traditional senses and by other more recently distinguished ones.

To my knowledge no one engaged in creativity research adopts the two above modes of thought in combination with the two focuses of thought described above as the framework for their theorizing[viii]. Hopefully, seeing any particular creative cognitive activity as a trajectory through the two dimensions above, and distinguishing various different kinds of creativity in terms of the trajectory, will give some order to a chaotic research area. Answering the ultimate question "Can creative ability be identified through some sort of testing and can it be taught or trained?" needs order beyond what the topic now exhibits.

Let us now become concrete and examine the creative cognition of a hypothetical director of an ongoing complex industrial construction project. The director will be constrained by a well-defined goal—accomplish a certain task on time and within budget. Executives will have, perhaps creatively, chosen the task and subordinates will have analytically determined the constraints. The executives' cognition would involve attempting to foresee the future in order to choose long-term goals, and their trajectory through my two dimensions would probably differ somewhat from that of a project director. We assume that our director has an intuitive sense

of normal progress including normal problems and normal solutions, based on managing or directing smaller projects. Circulating among the project's clients and employees, observing the work in progress, and reading progress reports and news items, the director is constantly acquiring new information, most of which is not surprising. Response, if any is required, will generally be intuitive and relatively effortless. Occasionally, a piece of information contradicts intuitive expectations. While the information is unexpected, it may still be of the sort with which the director has prior experiences, and an intuitive response will present itself. The director might want to give some analytical attention to the response, checking that prior experience is indeed applicable, before acting in a routine way.

Sometimes, however, the new information will be unique in the director's experience. Then, assuming the project director can turn to no trusted colleague who through experience can offer advice, analytical deduction using what might be called the director's mental model can consciously be used to predict subsequent events. Here, mental model refers to the director's conscious theory about the workings of the domain.[ix] Does the predicted immediate future based on the director's currently held perspective on the situation and with the new information treated as salient forebode a threat to the project's goal, or an opportunity to achieve results better than the stipulated two performance constraints? If so, a response is desirable.

If the director's mental beliefs about the project's environment and how various plausible decisions would affect it are themselves not novel, the response suggested by analysis might prove satisfactory, but would not be deemed creative. A more creative director would, before responding, ponder whether this new information would be less surprising given a different perspective on the situation.

The easy route to changing perspective, should it work, is to focus attention on the new information and on what according to the original perspective is background information. This can, in occasional cases and given appropriate prior experiences, cause some background information intuitively to become salient and a new perspective to present itself. As a result of this spontaneous intuitive reframing, what was surprising may no longer be so, and an intuitive response will occur to the project director. If the response proves, perhaps after analytical study, to be appropriate and is not one that other project directors would have produced, we have here our first example of a creative act, one attributable to the intuitive brain.

More often, this approach will fail because the situation is truly novel. Then a different kind of creative cognition—conscious, effortful reframing–

–is required. The test of a newly contemplated perspective is its ability, based on analytical cognition, to predict correctly the immediate subsequent events and to explain immediately preceding ones. If the new perspective is novel and the chosen act based on it is appropriate, the mind deserves credit for this creativity.

Let us suppose now that all reframing attempts fail to account for the intriguing or troubling newly acquired information. A director, deeply committed to the job, while possibly tempted to go on with business as usual, will find it impossible to put the anomalous new information out of mind. The world of the project will feel out-of-kilter, and a sense-making urge will trump complacency.

If a new perspective does not satisfy, the only sense-making alternative is a modification of the stimuli. Additional new information must be sought. While seeking enlightenment from colleagues, further investigative reports, or even gossip should not be eschewed, probably the project director's best source is his or her immense web of declarative memories, and associations among them, that has been acquired during formal education and during a career of involvement in the domain of the project. Declarative memories are either linguistic or episodic (i.e. memories of personal experiences) and declarative associations include not only relationships between nameable objects (e.g. pen and paper) but also between concepts (e.g. liberty and happiness)

Since we are examining creativity we assume that what are for the director obviously related personal memories, facts and concepts don't assuage the felt need for sense making. The key, if it exists, is not under the lamppost. The brain must bring sight, not coincidently called insight, to the darkness.

It appears that the truly creative mind now embarks on what is essentially a trial and error search going beyond obvious associated declarative memories to other memories distantly associated with the first obvious ones, and if necessary memories even deeper in this web of associations. I doubt that this can be a purely random search as some have suggested and speculate that intuition gleaned from experience distinguishes promising paths from unpromising ones. It is clear from my own experiences and many reported in the creativity literature that this deep associative memory search is most productively carried out when one is neither coping with routine details of the world of the project or consciously trying to make sense of its anomalies, but rather when one is relaxed. Creative thinkers have reported insightful *a ha* experiences with

accompanying elation while hiking in nature, when falling asleep, or, often, while dreaming. [x]

If the set of stimuli including the new insightful information is familiar based on one's experience, an intuitively obvious new perspective will present itself and intuitive prediction resulting from past experiences can be tested against reality. If, on the other hand, the situation is now seen as novel, detached analytical thought must be used to choose both perspective and the prediction. In either case, if the situation evolves as predicted, the director will feel elated because things seem now to make sense and the situation now permits what will be viewed by others as a non-obvious creative response.

If the situation does not so evolve, the creative mind must be capable of accepting temporary defeat with its accompanying remorse and of continuing the search. The project director must now struggle with the question: should I try to modify my chosen perspective on the situation including the insight or is there reason to question my intuitive or analytical prediction or have I simply not yet found the right stimuli on which to base my situational understanding? Here, for the involved, creative project director, persistence is non-negotiable and the search for sense continues. This can involve recycling to perspective reframing or to stimuli enhancement. Only intuition can guide this choice.

Summarizing, in attempting to understand creative cognition perhaps the most important issue is the choice of the critical dimensions of one's description. After studying the current neuroscientific literature, not generally concerning creativity but rather human or animal successful coping behavior in trivial decision situations amenable to brain magnetic resonance imaging or other experimental paradigms, I have concluded that the two modes of thought—intuitive and analytical—and the two focuses of thought—perspective and stimuli—are the essential elements of description. Furthermore, most creative cognition must be seen as an artful and effortful dynamic trajectory of thought rather than a momentary stroke.

Filling out the details of this process with respect to a hypothetical event in the life of a project director has led me to identify two kinds of creativity: situational reframing and situational enhancement. An act worthy of the designation "creative" can be the result of anything from effortful and successful reframing (an appropriate new perspective will only come intuitively and therefore easily if the situation is not truly novel in the career of the director and then the new frame would be useful but would not qualify as novel) to the cycling between stimuli enhancement and perspective determination until finally a situation makes predictive sense and

attention can then turn to the choice of an appropriate response. The best response to a novel situation, assuming a given perspective and taken-for-granted information set, is the subject of a large analytically-oriented decision-making literature and is beyond the scope of this paper. The issue here is the creative determination of the appropriate perspective and the appropriate informational elements of that analytical effort.

Once the nature of the cognition producing creativity is identified, the question naturally arises: the execution of which stages of the creative process can be improved by formal education or supported by computerized decision aids, which can be enhanced by some sort of experiential training, and which depend on personality traits of the individual involved? The first two parts of this question can be productively addressed only on the basis of an organizing theory of coping cognition in general and creative coping cognition in particular. We have here proposed such a theory. The third part goes beyond cognition, but it is important to note that to take advantage of any educational endeavor, the student learning to think creatively must possess personality traits driving him or her relentlessly forward in the quest despite almost inevitable failures and false starts along the path. This requires exceptional motivation due to dedication to one's domain of skilled performance.

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[i] William James (1890) investigated creativity and famously claimed that creativity requires the association of pieces of information held in one's declarative memory that others do not associate. Mednick (1962) and Eysenck (1993) later elaborated this view. I, in this paper, will argue that an associative process is one of two distinct kinds of creativity.

[ii] An exciting exception, an fMRI study of the *creative* act of jazz piano improvisation, is reported in Limb and Braun (2008).

[iii] This behavior is the subject of stage 5 of skill acquisition in Dreyfus and Dreyfus (1988) and S. Dreyfus (2004)

[iv] A dramatic example of how distinct the processing of the implicit brain is from that of the mind is found in Sacks (2007) pgs. 206-207 where he discusses Clive Wearing. A devastating brain infection left this musician with severe retrograde amnesia that robbed him of all the conscious reasoning and planning abilities associated with the analytical

mind. Yet he maintained the behavioral skills associated with the implicit subcortical brain. Wearing can not only perform entire pieces learned before his amnesia, but with others to put the music before him, to get him into action and to make sure that he learns and practices, Wearing can learn and proficiently play new pieces.

[v] "Rule" as used by certain behavioral neuroscientists refers to which of several stimuli should be the focus of attention in order to gain a reward during an experiment. "Rule" determines the correct perspective and "rule learning" is "correct perspective learning". See Rougier et al (2005). For these neuroscientists studying the intuitive brain, a learned rule is an abstract pattern of activity in a certain part of the brain and not something that can be articulated using language, as it can in the "rule-based behavior" claimed for the mind in the artificial intelligence literature.

[vi] Intuitive perspective is the subject of stage 4 of Dreyfus and Dreyfus (1988) and S Dreyfus (2004) while chosen perspective is the subject of stage 3 of these references.

[vii] See Rougier et al (2005) and Buschman and Miller (2007).

[viii] Dietrich (2004), in Figure 1 on page 1018, proposes a distinction between two processing modes equivalent to the implicit and analytical brains, in conjunction with two "knowledge domains" that, however, do not correspond to my two focuses of thought.

[ix] Mental models useful in novel situations exist in the mind, but have no counterpart in the implicit brain. After considerable experience, the implicit brain can learn correctly to predict in a familiar situation by suitably adjusting synapses based on events observed after that situation, just as it can learn to act appropriately by other synaptic adjustments based on successful behaviors.

[x] The fMRI study of jazz improvisation of Limb and Braun (2008) observed extensive deactivation of the brain region associated with the top-down gating mechanism producing perspective. Interestingly, this seems to jibe with Friedrich Schiller's famous speculation, in response to a letter from his friend Christian Gottfried asking about the source of his creativity, that creativity involved relaxing the watcher at the gates of the mind. He wrote: "The intellect has withdrawn the watcher from the gates and ideas rush in pell-mell, and only then does it review and inspect the multitude."

Quite a few neuroscientists, among them Heilman et al (2003) and Aston-Jones and Cohen (2005), have noted that, while the stimulation of neurons that produce the neuromodulatory chemical compound norepinephrine seems to focus top-down attention on a perspective's salient stimuli, low norepinephrine level which occurs during relaxation and sleep seems to defocus perspective. Perhaps norepinephrine is the watcher that Schiller sensed was withdrawn.

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