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Incubated Cognition and Creativity

***Abstract**: Many traditional theories of creativity put heavy emphasis on an incubation stage in creative cognitive processes. The basic phenomenon is a familiar one: we are working on a task or problem, we leave it aside for some period of time, and when we return attention to the task we have some new insight that services completion of the task. This feature, combined with other ostensibly mysterious features of creativity, has discouraged naturalists from theorizing creativity. This avoidance is misguided: we can maintain unconscious incubated cognition as (sometimes) part of the creative process and we can explain it in scientifically responsible ways. This paper, focusing on the effects of attention on the functional networking of the brain, attempts just such an explanation. It also serves to assuage the naturalist's scepticism about other features of creative cognition. The broad upshot, one would hope, is that philosophers of mind and cognitive scientists return some attention to the long neglected topic of creativity.*

Creativity scares naturalists. Traditionally, this has been the case for a number of reasons, sometimes disparate sometimes connected. One such reason consists in an extreme analysis of creativity that insists upon locating creative thought in unconscious, free-associative thought.

Based largely upon the introspective reports of Hermann von Helmholtz, psychologist Graham Wallas distinguished four stages of creative cognition (Helmholtz, 1896; Wallas, 1926; this distinction was also made by Poincaré, [1902–8]1984 and Hadamard, 1954). *Preparation* involves acquisition and application of skills and

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knowledge to some problem or task. *Incubation* occurs when conscious attention is diverted away from the problem. The third stage involves a moment or moments of *illumination*. The name here implies that after incubation creative insight flashes into sight. The fourth stage is one of *verification*. Here the initial insight is subjected to evaluation and criticism. Many theorists of creativity have endorsed this basic framework and put heavy emphasis on the incubation stage. According to these views, creativity requires incubation: a cognitive system can produce a creative thought *t* only if some of the processing that enabled *t* is incubated. Call any such theory *incubation essentialism* (Koestler, 1964; Martindale, 1977; 1981; 1990; 1995; 1999; Mendelsohn, 1976).

What then is incubated cognition? Arthur Koestler cites a lecture given by Henri Poincaré in 1908, where Poincaré considers the following dilemma (Koestler, 1964, pp. 164–5). During creative thought processing, ideas are combined in novel ways, and this combination is performed largely unconsciously, by what Poincaré calls the *subliminal self*. For Poincaré there are only two ways we might think of the unconscious. One, we might think of the unconscious in Freudian terms, as a self capable of careful and fine discernment and, importantly, distinctions and combinations that the conscious self fails to make. This implies that the unconscious mind is superior to the conscious mind. Poincaré doesn't like the sound of this, and so opts for what he takes to be the only other option: we should think of the unconscious as a sub-personal automaton that mechanically runs through various combinations of ideas.

> Figure the future elements of our combinations as something like the hooked atoms of Epicurus. During the complete repose of the mind, these atoms are motionless, they are, so to speak, hooked to the wall. During a period of apparent rest and unconscious work, certain of them are detached from the wall and put in motion. They flash in every direction through the space … as would, for example, a swarm of gnats, or if you prefer a more learned comparison, like the molecules of gas in the kinematic theory of gases. Then their mutual impacts may produce new combinations (cited in Koestler, 1964, p. 164).

Poincaré and others thus think of incubation as a stage of cognitive processing run either by a Freudian subconscious self *or* a sub-personal automaton, generating random conceptual associations.

These considerations motivate an argument, call it the *Argument from incubation essentialism*, which captures the cause for the naturalist's fright.

(1) Creativity requires incubated cognition.
(2) Incubated cognition requires a subliminal self
(3) A subliminal self requires (a) a Freudian unconscious or
(b) a sub-personal automaton.
(4) (a) and (b) are outside of the naturalist's purview.

(C) Incubated cognition is out of the naturalist's purview.
(C_2) Creativity is out of the naturalist's purview.

The first conclusion (from (2), (3), and (4)) encourages *incubation phobia*: if creative cognition requires *that kind* of cognition, then there is little if anything that scientifically minded theory can say about it. There is ample room for response here: one might deny (4) by offering a naturalistic model of (a) or (b). One might deny (3) by offering some third way to understand the subliminal self. One might deny (2) by modelling incubated cognition in a way that requires nothing like a subliminal self . (These last two moves thus argue through Poincaré's dilemma.) Any of these moves is sufficient to bar the inference to (C). The model offered below is probably best understood as a denial of (2).

The second conclusion (C_2) follows from (1)-(C). Thus one simple way to bar this inference, in addition to those offered above, is to weaken (1) for something like (1′) Creativity involves incubated cognition. This is simply to deny incubation essentialism. But a conclusion like (C_2) is supported in other ways, for example by acknowledging some other purportedly spooky features of creativity. Here are two such features. Creativity requires, as a conceptual point, genuine novelty. To be creative, an *F* must be new with respect to some system: social, cognitive, environmental, biological. Genuine novelty implies *ex nihilism*: creative *F*s emerge from nowhere. And science has got nothing on nowhere. Second, creative ideas often come to their bearers unbidden like bumps on the head. We describe such ideas as ones that 'just happen' or 'just come to us' unwilled in flashes or bursts of insight. This *flash phenomenology* mocks naturalism: unwilled creative insight inspires inspirationalism which, it has been argued since Plato, is outside of the naturalist's purview. These considerations conjoined with arguments like the one offered above have proven sufficient to keep the naturalist away, for the most part, until now.[1]

[1] There are exceptions: Boden (1994; 2004); Dartnall (2002); Finke *et al*. (1992); Gabora (2000; 2002); Simonton (1999); Smith *et al.* (1995); Sternberg (1999); Weisberg (1986; 1995; 1999).

But these two extremes can be avoided. We can split the difference between incubation essentialism and incubation phobia, maintaining unconscious incubated cognition explained naturalistically. And, as a bonus, we will exorcise some additional spooks in the process.

Incubation Effects and Unconscious Cognitive Processing

In a series of experiments, psychologists Steven Smith and Steven Blankenship studied what they call *incubation effects*: instances where subjects have greater success solving an initially unsolved problem after setting it aside for a period of time (Smith and Blankenship, 1989; 1991; see also Smith *et al.*, 1995). They begin with the hypothesis that failed problem solving often depends upon *fixation*: subjects retrieve or construct incorrect strategies for and solutions to the problem and then suffer a mental block from the correct one/s.[2] The fix for fixation? Forget it. Smith and Blankenship propose and test the *forgetting-fixation* hypothesis which suggests that overcoming fixation is crucial to making unsolved problems solvable. After initial presentation of a problem, they induce fixation in subjects by priming them with incorrect solutions. The subjects are then either retested immediately or after a period of time. The second group, those who presumably had time to forget the fixated (incorrect) solutions, did consistently better than the first group upon retesting.[3] These studies are instructive: they provide behavioural evidence for what were otherwise mere introspective reports. And, they identify attention as an important cognitive dimension in considerations of incubation.

This insight already puts us in position to avoid some of the non-naturalistic worries mentioned above. Acknowledging incubation effects only commits us to the thesis that some information processing in a cognitive system occurs at an unconscious level. These processes are not part of phenomenal conscious experience, but nonetheless may causally affect such experience.[4] This alone does not entail a

[2] Fixation was first studied by Woodworth and Schlosberg (1954).

[3] Also worth mentioning is that the second group were given 'filler tasks' during the incubatory period. These tasks were reportedly very difficult and were stressed as no less important to the subjects. So the subjects were still cognitively engaged during the incubatory period.

[4] Ned Block distinguishes *access consciousness* from *phenomenal consciousness* (Block, 1995). The notion of phenomenal consciousness derives from Thomas Nagel (1979). A system or organism is phenomenally conscious if and only if there is something it is like to be that system or organism. A state or process of an organism is phenomenally conscious if and only if there is something it is like to be in that state or process. Access consciousness

commitment to a subconscious self or a sub-personal automaton. It only commits us to unconscious cognitive processing.

Psychologist Colin Martindale proposes the *cortical arousal theory*.[5] We can use some of his points of emphasis as a starting off point for our own model. Martindale's theory centres on a claim that *defocused attention* to a stimulus, which results from a decrease in overall cortical arousal increases the range of concepts or associations brought to bear on that stimulus. The point can be put in the terms of neural networks: defocused attention results in a greater activation of nodes in a network, though the strength of the activation of each node is relatively equal. By contrast, when attention is sharply focused, a few nodes are highly activated (Martindale, 1995; see also Rumelhart *et al*., 1986). Martindale uses these points to infer a sharp distinction between creative and uncreative persons. But we can borrow his basic insight without endorsing such an inference. Decreased but broadly spread attention increases the conceptual associations that figure into the cognitive processing of a stimulus or task.[6] This is when unconscious processing does its work. The range of relevant concepts widens and the potential for creative insight increases. We extract the following lessons from Martindale: important to creative thought, incubated or not, is the range of attention, the quantity of conceptual associations, and the degree of cortical arousal.

Hebbian Cell Assemblies and Neural Plasticity

Donald Hebb famously used the term 'cell assembly' for clusters of neurons that constitute a circuit for continued (post-stimulus) neural activity. These assemblies form as a result of the synchrony and proximity of the firing of individual cells. Hebb describes their formation as follows: 'any two cells or systems of cells that are repeatedly active at the same time will tend to become "associated", so that activity in one facilitates activity in the other' (Hebb, 1949, p. 70).

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is more subtle, but the following gloss is sufficient for our purposes. A state or process is access conscious if it is available for judgment and inference — it can be attended to, can be the subject for belief and other states, can be evaluated, can figure into reasoning, etc. Such states or processes are thus *potentially* the object of current attention, but need not *actually* be attended to (see also Davies, 1995, pp. 359–64). Note that a commitment to incubated cognition is silent with respect to access consciousness.

[5] Martindale's work owes much to a number of psychologists before him, most notably Hull (1943); Mednick (1962); Mendelsohn (1976).

[6] *Spreading-activation* theories of various cognitive capacities — for example, semantic processing and memory — are closely related. See Collins and Loftus (1975) on semantic processing, and Anderson (1983) and Gabora (2002) on memory.

Hebbian learning takes conceptual root in the notion of cell assemblies.

> Let us assume then that the persistence or repetition of a reverberatory activity (or 'trace') tends to induce lasting cellular changes that add to its stability. The assumption can be precisely stated as follows: *When an axon of cell* A *is near enough to excite a cell* B *and repeatedly or persistently takes part in firing it, some growth process or metabolic change takes place in one or both cells such that* A's *efficiency, as one of the cells firing* B*, is increased* (Hebb, 1949, p. 62)

These *reverberations* and the changes they cause ultimately result in the formation of closed, semi-autonomous systems of neurons — cell assemblies — which can activate in the absence of the initiating stimulus. Neural structures thus change with the learning of new concepts, skills, and information.

Memory recall, on the Hebbian model, involves activating neurons in specific patterns along the suggested pathways. This has prompted many theorists to endorse a model of *distributed* memory (or cognitive processing more generally). On such models, memories are not found at particular locations in the brain, as we commonly think of it, but rather via particular patterns of neural activation (Hinton and Anderson, 1981; Hinton *et al.*, 1986; Kanerva, 1988; Willshaw, 1981). On such models, the ability to recall a memory depends upon the connections (and their strengths) between neurons and the nature of the present stimulus — that is, whether the present stimulus evokes a similar pattern of neural activation. The first — the strengths of the connections constituting the cell assembly — are determined by the principles of Hebbian learning briefly articulated above. Finally, each of the neurons activated during memory recall will of course correlate with other memories: we thus have the experience of one memory leading to another. Functional brain structure thus involves a vast network of connections between its individual neural cells, and these connections are essential to learning, memory, and other cognitive functions and are continually changed by our interactions with the world.[7]

[7] Hebbian terminology will be used throughout. In some ways this is just useful shorthand, since there are several contentious issues that attach to the respective terms and many terminological variations offered in the 50 plus years since their initial publication. The conceptual fundamentals are still widely accepted by a range of physiologists, psychologists, and computational scientists (see Orbach, 1998, for an overview; see also Amit, 1995; Braitenberg, 1989; Fentress, 1999; Palm, 1982; Seung, 2000;). Many have been critical of, among other things, the notion of reverberation (Milner, 1957; 1999), of the capacities for discrimination of associations, memories, and concepts given the closed nature of Hebbian assemblies (Hopfield and Tank, 1986), and of the apparent lack of constraints on the growth of cell assemblies and the threshold for activation of such assemblies (Milner,

This last feature of the Hebbian legacy is most important: quite simply, we change our brain by interacting with the world. More specifically, continued attention to a problem, what some have called *cerebral effort*, causes changes in the networking of the brain's cortex (Donald, 2001, pp. 175–8). In Hebbian terms, continued attention to a stimulus strengthens the connections between neurons in existing cells and/or creates new connections and thus new cell assemblies. This is consistent with a more general point about *neural plasticity*. Current neuroscience models the brain as an organic structure — rather than as a rigid 'knowledge-independent, hardware construct' — stable in genetic material but constantly undergoing functional change and development in neural networking in response to external stimuli (Young, 1951; Rosenblatt, 1961; Von der Malsburg, 1973; Pettigrew, 1974; Changeux and Dauchin, 1976).[8] 'Plasticity' thus refers, broadly, to the neurophysiological capacity for functional arrangement and re-arrangement. Attention changes not only *neural activation* but *neural structure*, and it does the second by doing the first. We have now to ask how attention can effect such change.

Attention and Automaticity

> Everyone knows what attention is. It is the taking possession by the mind in clear and vivid form of one of what seem several simultaneous objects or trains of thought (James, 1892).

James was right: attention is a perfectly understandable folk concept. However, to understand the connection between attention and neural plasticity, we need to think of the former in terms of its neural correlates.[9] And our interest is in something broader than the object-based perceptual attention that neuroscientific research focuses most on.[10] We are concerned with *cognitive attention* or what some call *executive attention* (Norman and Shallice, 1986), which is inclusive of but not

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1999). Nonetheless, these criticisms and amendments maintain the core features of Hebb's proposals, and a complete analysis of the logical space is orthogonal to our concerns. It will thus be assumed that Hebb's basic substantive framework adequately models the network structure of the brain (at least at the level of abstraction needed here).

[8] Neural Darwinists take the degree of plasticity to its extreme (Changeux and Dehaene, 1989, p. 100; see also Edelman, 1987; Calvin, 1989).

[9] Use of a term like 'correlation' betrays the fact that important philosophical questions are being begged: some kind of physicalism, though not of any particular stripe, is assumed throughout this paper. 'Correlation' is thus a kind of dummy term for the relation, whatever that relation should turn out to be, between mental states and processes *and* brain states and processes.

[10] For example, much of the neuroscientific literature focuses on perceptual *alerting*, *orienting*, and *feature integration* (see Posner and Bourke, 1996; Umilta, 2001).

exclusive to perceptual attention. We can understand it at a folk level of description by, again, following James: we can attend to objects external or internal, to a moving figure in the visual field, a train of thoughts, or a cognitive challenge. At a neural level of description: drawing attention to some object *o* correlates with the facilitation of the neurons or neural networks normally excited by *o*s or *o*-like objects (Milner, 1999, p. 33). Thus attending to thoughts about cherries could, most simply, be prompted by a perceptual experience as of cherries. Or, it could be prompted by some other related stimuli (small fruit-bearing trees, home-baked pie, a terrible song by a terrible heavy metal band in the early 90s) or some other related mental state (an intention to buy cherries at the market). This reveals the connection between plasticity and attention: attention involves continuous neural activation which strengthens synaptic connections and thus contributes to the continued shaping of the brain.

This motivates a simple (and somewhat unsurprising) hypothesis: attending to and performing cognitive tasks affects neural networking. This hypothesis is confirmed by a variety of experimental research (Posner *et al*., 1997; Posner and Raichle, 1994; see also Karni *et al*., 1995; Nudo *et al*., 1996). Using fMRI and PET scanning and imaging techniques, this research confirms a variety of changes in neural structure and activity corresponding both to the practice and eventual acquisition of mundane but high-level cognitive skills, and to the attention and effort required for these processes. (For example, Posner *et al.*, 1997, focused on reading, arithmetic, and object recognition.) What kinds of changes are we talking about?

We can look to William James once more.

> But actions originally prompted by conscious intelligence may grow so automatic by dint of habit as to be apparently unconsciously performed. … Shall the study of such machine-like yet purposive acts as these be included in Psychology?' (James, 1890, pp. 6–7).

The answer, at least if the question is descriptive, is yes. A behavioural consequence implied by Hebbian learning and born out by the behavioural studies of Posner and others shows us why. With continued effort on and attention to a problem — what we would more commonly call 'practice' when referring to skill acquisition — portions of the task or skill become automatic. These automatic processes are typically understood as involuntary and unconscious (Kahneman and Treisman, 1984; Posner, 1978).

Thus what begins as an activity involving highly focused executive attention, becomes one that is (partially) automatic. Learning another language or a musical instrument, for example, like just about any cognitive task, will begin with conscious attention to each stage of the task. With time, however, conscious control makes way for automatic performance. There is an intuitive evolutionary reason for this.

> If an act became no easier after being done several times, if the careful direction of consciousness were necessary to its accomplishments in each occasion, it is evident that the whole activity of a lifetime might be confined to one or two deeds' (Maudsley, 1876).

Thus if we didn't internalize elements of a task, we wouldn't perform many of them. The move towards *automaticity* is thus a move towards *efficiency*.

This efficiency is largely enabled by a reduction in the potential for interference in processing. Conscious attention requires, well, attention: we must focus our efforts on one stimulus or set of stimuli and keep it there. Automatic processing, by contrast, is less prone to interference. This is for the simple reason that it involves fewer regions of the brain; it involves a decrease in the expanse of cortical arousal. This is a fact observed by neuroscientists since the early part of the last century. The overall brain activity in organisms is considerably less when the stimulus is conditioned versus when it is novel. (See Durup and Fessard, 1935, for the earliest studies; more recently, see John and Killiam, 1959; Pigarev *et al.*, 1997.) These results are also observable in human brains. Using PET imaging, the brains of children before and after learning computer games were compared. After just a few weeks of practice, the range of cortical surface arousal decreased in spite of a sevenfold improvement. In fact, the study showed that the greater the improvement, the greater the decrease in activation range (Haier *et al.*, 1992; for similar studies see Petersen *et al.*, 1998; Karni *et al.*, 1995; Buckner *et al.*, 1995; Desimone, 1996). So the more we practise doing something, the less of the brain we will use in doing it: conscious practice results in a more restricted range of cortical involvement. This cuts down on interference, since less irrelevant information will cloud performance of the task (Edelman and Tononi, 2001, pp. 58–61). Subjectively, a task feels much easier, if not effortless, when we no longer must attend to, for example, the difference between certain verb tenses or guitar chords.

Even though the regions of the activated cortex become fewer with practice and automaticity — the activation *area* decreases — the connectivity in those (activated) regions may continue to increase. Decreased cortical arousal does not entail a decrease in the formation and augmentation of cell assemblies. The opposite is likely to be true.

Since the activation is more localized, the chances of proximal neurons firing synchronously is increased, and with it the chances of the creation or strengthening of a connection between those cells. Edelman and Tononi offer the following metaphor. 'It is as if, at first, an initially distributed and large set of cortical specialists meets to try to address a task. Soon they reach a consensus about who among them is best qualified to deal with it, and a task force is chosen. Subsequently, the task force recruits the help of a local, smaller group to perform the task rapidly and flawlessly' (Edelman and Tononi, 2001, p. 61). A shift from conscious attention to partially automatic performance thus increases the efficiency with which we can perform cognitive tasks. It accomplishes this *both* by decreasing the area of activation and increasing the networking complexity in the brain.

Back to Incubation

We see how all of this speaks to incubation, and creativity more generally, by considering the subjective consequences of plasticity and attention. Automaticity, as mentioned above, makes a cognitive task easier to perform. This is why experts don't just make it look easier, it *is* easier. Second, automaticity frees up cognitive resources to take on other parts of the task. If a task requires a particularly creative solution, then the more work done automatically the better, since we can continue to practise not-yet-mastered components of the task and ultimately secure a solution or complete the task. Finally, it contributes to that sense that 'your brain is working for you' and you aren't working it. Initially, we might be consciously aware of various associations or memories relevant to the task at hand, and then move on to others. But the relevant associations, correlating with cell assemblies, remain active. This activation can contribute to additional connections, or strengthening thereof, between assemblies and other cells. Given the right stimulus, these new or newly strengthened assemblies may be activated (or re-activated) while one is attending to some other feature of the task, some other cluster of associations. Sometimes the conceptual associations that surface are creative or lead to others that are. All of this then, is consistent with and (at least partially) explanatory of the introspective reports with which we began.

But now we incur a worry. We have the makings for a model of incubated cognition, but they underdetermine just how the model should look in the following way. We might opt for (at least) either of the following two options.

(IS) Incubatory solution thesis:

The incubation stage is a stage of lessened or weakened attention to some elements of a task or problem *x*. During this period, activation and strengthening of cell assemblies continues (after the initiating stimulus). Some of this activity results in a solution to *x* (or something near it). When one returns conscious attention to *x*, the original pattern of cell activation occurs plus activation of the newly formed or newly strengthened ones.

From a subjective point of view, a solution (new association[s]) just comes to us when we return to the problem. (IS) implies that a solution occurs during incubated cognitive processing.

Alternatively, we might opt for the:

(IP) Incubatory preparation thesis:

The incubation stage is a stage of lessened or weakened attention to some elements of a task or problem *x*. During this period, activation and strengthening of cell assemblies continues (after the initiating stimulus). (Note that this is the same as [IS] up to this point). During the incubated period, cognitive effort can be directed elsewhere. In the meantime, much of the work is 'done for you' so that when conscious attention is returned to *x*, new or newly strengthened associative connections have been formed. Some of these associations prove relevant to *x*. With (post-incubatory) attention paid to *x*, including to the newly developed or strengthened associations (i.e. we keep at the problem), a solution may be secured.

From a subjective point of view, a solution comes much easier when we return to the problem since we are much better prepared to solve it. (IP) implies that a solution is enabled by the preparatory work that occurs during the incubatory period.

Again, the data and theory we have considered supports both theses, how then do we choose? We don't have to. We have provided a conceptual and neuropsychological basis for *incubated cognitive processing*, and a choice between (IS) or (IP) makes little difference to this fact. Moreover, the two theses are not exclusive: it is likely that sometimes (IS) is a true description of how incubated cognitive processing yields an *incubation effect*, and sometimes (IP) is the true description.

We have thus sketched a model for incubated cognition. We have identified the importance of attention and of unconscious, automatic processing. Using a Hebbian framework, coupled with empirical studies from the neurosciences, we have provided a neuropsychological basis for our initial conceptualization. In brief, the explanation goes roughly as follows. Attention to a stimulus increases the number and density of connections between neural cells and assemblies. Continued attention to that stimulus (what we ordinarily call 'practice') decreases the area of cortical arousal, resulting in some degree of automatic information processing. At this point, attention is diverted and post-stimulus activation in these assemblies continues. This is *incubated cognitive processing*. This processing may enable or result in useful or novel, perhaps even creative associations. These are *incubation effects*.

Note then that we have distinguished incubation into two components: incubated cognitive processing and incubation effects. The first, though it is unclear precisely where to demarcate it, is in line with our initial characterization: it is a period where conscious attention is removed from some stimulus, but unconscious cognitive processing continues with regard to that stimulus. An incubation effect is a conscious mental upshot of that period: a solution, insight, or thought. Note that nothing in this characterization requires that incubation effects be novel and thus, *a fortiori*, there is no requirement that they be creative. One could have a thought which resulted from incubation, but which was not, as a matter of fact, novel with respect either to one's own mind or some other criterion.

Now recall the choice between incubation essentialism and incubation phobia. How does our model balance between the two? Incubation essentialism requires incubation for creativity: without the first, you don't get the second. Even without our model, we can introspect counterexamples against this view. Assuming you've had a creative idea or two, haven't some of them come when you were consciously attending to the problem? If not, isn't this surely possible? The answer seems an obvious yes and so, at least phenomenologically, incubation essentialism looks false. We can also use the basics of our model to show the neuropsychological implausibility of essentialism. Our analysis certainly supports the hypothesis that *some* creative thoughts result from incubation, but it does not support the claim that *all* such thoughts are so explained. Practice, attention, and effort may induce decreased cortical arousal and automaticity, but not necessarily before cognitive benefits can be gained from those efforts. Neural networking can change very quickly (assuming that is even necessary for a creative thought), so surely a creative solution to a task or problem may be secured *before* a decrease in attention and conscious effort, that is, before incubation. Thus incubation is not, as modelled, essential to creative thought.

Now for incubation phobia. Our model offers at least two advantages. First, we have maintained naturalism, but have done so without eliminating our target explanandum: we have modelled incubated cognition as consistent with the introspective and behavioural conceptualizations and have done so in scientifically responsible ways. Second, incubation as we have modelled it is *not* basic or specific to creativity. Incubated cognitive processing is a basic capacity — enabled by neural plasticity and the effects of attention — fundamental to a variety of cognitive abilities (memory, learning, and mastery of cognitive tasks, skills, and information). So there is some reduction here: incubated processing is important to creativity *because* it is important to how we learn, practice, and engage with novel tasks, skills, and information — how we are capable of cognitive novelty. But note the reduction is not one to learning *simpliciter*, but to what we might call, as it were, *learning without looking*. We can learn new things and skills without looking, that is, without paying conscious attention (for at least some portion of the cognitive process). Incubation is important for these reasons *even if* it results in no creative output. It is thus an explanandum for any naturalist: it is not something the naturalist should be frightened of but rather should consider herself obligated to explain.

We thus split the difference between incubation essentialism and incubation phobia.

A Final Note to Other Spooks

This model also accommodates flash phenomenology, at least when creative thoughts result from incubation. If we return to a stimulus after periods of incubation (or even just maintain our focus on that stimulus for a period of time in a non-incubated case) newly established or strengthened associative connections may be activated. If we take seriously the basic posit that memories, concepts, associations, etc., are 'located' via certain patterns of activation, when we attend to the right stimulus, the cell assemblies correlative with these mental entities may be activated via some network or another. From a subjective point of view, this translates to the experience of an idea popping into our heads. There is nothing mysterious about this: it is a simple, though no less remarkable, feature of cognitive processing.[11]

Recall *ex nihilism*, which says that given their novelty, creative ideas emerge from nowhere. Our model shows that, one, they come from somewhere and, two, they are not unlike lots of uncreative ideas in this respect. Creative thoughts are bound to particular cognitive profiles. Consider a thought which is an incubation effect. This thought depends (in part), according to our model, upon new or newly strengthened connections between neural cells and cell assemblies. These neural changes depend upon previous stimuli and the resultant cell assemblies (and the strength of their synaptic connections), upon current stimuli, upon attention, upon the degree of automaticity involved in processing. Some of these new connections surface in consciousness as novel ideas. Assume that whatever other conditions one puts on creativity are satisfied: the thought in question is creative.[12] Note then that this maintains a genuine novelty without invoking *ex nihilism*: the thought hardly came from nowhere, it depended upon a number of states or properties of the cognitive profile. If we can offer this explanation in the incubated case, there is little reason to think that we cannot offer it in the non-incubated case.

We close with the following simple moral: cognitive novelty is possible given the plastic nature of the brain. There is nothing paradoxical about such novelty, as some have suggested. It is symptomatic of the neural plasticity and the effects of attention on that plasticity, which is essential to our acquisition of cognitive abilities, skills, and information. It is thus that we are able to complete one task or many, to solve new and difficult problems, and, sometimes, to think creatively. This feature is not specific to creativity. In fact, it is not not specific to incubated cognition. It is a general feature of cognition. But focusing on incubated cognition as one way creative thoughts are tokened makes the general lesson salient.

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[11] A purely philosophical response to the threat of flash phenomenology goes as follows. We must be careful to distinguish the phenomenology of mental states from certain metaphysical facts about such states. Beliefs, desires, and memories, among others, also just come to us in flashes. In fact, we cannot (some say) execute immediate voluntary control over such states (Alston, 1989; Bennett, 1984; 1990; Millgram, 1997; Williams, 1973). They come to us when they do; and we struggle to change them even when we want. This fact (if we grant it) is not, however, sufficient to strip the responsibility for such states from the agents in question, nor to imply any other inspirationalist or irrationalist explanations thereof. We can maintain flash phenomenology of mental states — be they beliefs, creative thoughts, or whatever — and explain them naturalistically. Mental states may *feel* a certain way, but that does not imply that they *are* a certain way.

[12] So note that the account offered is non-committal to any one definition of creativity.

There are many degrees of freedom along which instances of incubation could stray from the proposed model. And a complete model would require treatment of many fine-grained neurophsyiological and neurocomputational details. What's offered here is a psychologically informed start to a full theory of incubated cognition: an indication of the conceptual machinery and empirical data needed to explain the phenomenon. This is a significant step beyond the (often non- naturalistic) analyses that have come before. And, as a bonus, we have revealed the scientific tractability of some other traditionally spooky features of creativity. This analysis should thus give the naturalistic philosopher of mind and the cognitive scientist another good reason to return serious attention to creative cognition.[13]

References

Alston, W. (1989), 'The deontological conception of epistemic justification,' in *Epistemic Justification* (Ithaca, NY: Cornell University Press).

Amit, D. (1995), 'The Hebbian paradigm reintegrated: Local reverberations as internal representations', *Behavioral and Brain Sciences*, **18**, pp. 617–57.

Anderson, J.R. (1983), 'A spreading activation theory of memory', *Journal of Verbal Learning and Verbal Behavior* , **22**, pp. 261–95.

Bennett, J. (1984), 'Deciding what to believe,' in *A Study of Spinoza's Ethics* (Indianapolis, IN: Hackett).

Bennett, J. (1990), 'Why is belief involuntary?' *Analysis* , **5**, pp. 87–107.

Block, N. (1995), 'On a confusion about a function of consciousness,' *Behavioral and Brain Sciences*, **18**, pp. 227–87.

Boden, M. (ed. 1994), *Dimensions of Creativity* (Cambridge, MA: MIT Press).

Boden, M. (2004), *The Creative Mind*, 2nd Edn. (London: Routledge).

Braitenberg, V. (1989), 'Some arguments for a theory of cell assemblies in the cererbral cortex', in *Neural Connections, Mental Computation* , ed. L. Nadel, L. Cooper, P. Culicover and R. Harnish (Cambridge, MA: MIT Press).

Buckner, R., Peterson, S., Ojemann, J., Miezin, F., Squire, L., Raichle, M. (1995), 'Functional anatomical studies of explicit and implicit memory retrieval tasks', *Journal of Neuroscience*, **15**, pp. 12–29.

Calvin, W. (1989), *The Cerebral Symphony: Seashore Reflections on the Structure of Consciousness* (New York: Bantam).

Collins, A., and Loftus, E. (1975), 'A spreading activation theory of semantic processing', *Psychological Review*, **82**, pp. 407–28.

Changeux, J.P. and Danchin, A. (1976), 'Selective stabilisation of developing synapses as a mechanism for the specification of neuronal networks', *Nature*, **264**, pp. 705–12.

Changeux, J.P. and Dehaene, S. (1989), 'Neuronal models of cognitive function', *Cognition*, **33**, pp. 63–109.

Dartnall, T. (ed. 2002), *Creativity, Cognition and Knowledge* (Westport, CT: Praeger).

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Davies, M. (1995), 'Reply to Searle: Consciousness and the varieties of aboutness', in *Philosophy of Psychology* , ed. C. Macdonald and G. Macdonald (Oxford: Blackwell).
Desimone, R. (1996), 'Neural mechanisms for visual memory and their role in attention', *Proceedings of the National Academy of Sciences of the United States of America*, **93**, pp. 13494–9.
Donald, M. (2001), *A Mind So Rare: The Evolution of Human Consciousness* (London: Norton).
Durup, G., & Fessard, A. (1935), 'L'ectroencephalogramme de l'homme', *Annual Psychology*, **36**, pp. 1–32.
Edelman, G. (1987), *Neural Darwinism* (New York: Basic Books).
Edelman, G. and Tononi, G. (2001), *A Universe of Consciousness* (New York: Basic Books).
Fentress, J. (1999),'The Organization of Behaviour Revisited', *Candian Journal of Experimental Psychology*, **53**, pp. 8–19.
Finke, R., Ward, T. and Smith, S. (1992), *Creative Cognition* (Cambridge, MA: MIT Press).
Gabora, L. (2000), 'Toward a theory of creative inklings', in *Art, Technology, and Consciousness*, ed. R. Ascott (Oxford: Intellect Press).
Gabora, L. (2002), 'Cognitive mechanisms underlying the creative process', in *Proceedings of the Proceedings of the Fourth International Conference on Creativity and Cognition*, ed. T. Hewett and T. Kavanagh, pp. 126–33.
Hadamard, J. (1954), *An Essay on the Psychology of Invention in the Mathematical Field* (New York: Dover).
Haier, R. Siegel, B.V. Jr., MacLachlan, E., Soderling, S., Lottenberg, S. and Buchsbaum, M. (1992), 'Regional glucose metabolic changes after learning a complex visuospatial/motor task: A positron emission tomographic study', *Brain Research*, **570**, pp. 134–43.
Hebb, D. (1949), *The Organization of Behavior* (New York: Wiley).
Helmholtz, H. von (1896), *Vorträge und Reden* (Brunswick: Friedrich Viewig und Sohn).
Hinton, G., and Anderson J. (ed. 1981) , *Parallel Models of Associative Memory* (Hillsdale, NJ: Lawrence Earlbaum Associates).
Hinton, G., McClelland, J.L. & Rummelhart, D.E. (1986), 'Distributed representations' in *Parallel Distributed Processing: Explorations in the Microstructure Cognition*, ed. D.E. Rummelhart and J. L. McClelland (Cambridge, MA: MIT Press).
Hopfield, J. and Tank D. (1986), 'Computing with neural circuits: A model', *Science*, **233**, pp. 625–33.
Hull, C. (1943), *Principles of Behavior* (New York: Appelton-Century-Crofts).
James, W. (1890), *The Principles of Psychology, Vol. 1* (New York: Holt).
James, W. (1892), *Psychology: The briefer course* (New York: Holt).
John, E. and Killiam, K. (1959), 'Electrophsyiological correlates of avoidance conditioning in the cat', *Journal of Pharmacological and Experimental Therapeutics*, **125**, p. 252.
Kahneman, D. & Treisman, A. (1984), 'Changing views of attention and automaticity', in *Varieties of Attention*, ed. R. Parasuraman and D.R. Davies (New York: Academic Press).
Kanerva, P. (1988), *Sparse Distributed Memory* (Cambridge, MA: MIT Press).
Karni, A., Meyer, G., Jezzard, P., Adams, M. M., Turner, R., & Ungerleider, L. G. (1995), 'Functional MRI evidence for adult motor cortex plasticity during motor skill learning', *Nature*, **377**, pp. 155–8.
Koestler, A. (1964), *The Act of Creation* (New York: Macmillan).

Martindale, C. (1977), 'Creativity, consciousness, and cortical arousal', *Journal of Altered States of Consciousness*, **3**, pp. 69–87.
Martindale, C. (1981), *Cognition and Consciousness* (Homewood, IL: Dorsey Press).
Martindale, C. (1990), 'Creative imagination and neural activity', in *The Psychophysiology of Mental Imagery*, ed. R. Kunzendorf and A. Sheikh (New York: Baywood).
Martindale, C. (1995), 'Creativity and connectionism', in *The Creative Cognition Approach*, ed. S. Smith, T.B. Ward, and R. Finke (Cambridge, MA: MIT Press).
Martindale, C. (1999), 'Biological bases of creativity', in *Handbook of Creativity*, ed. R. Sternberg (Cambridge, MA: Cambridge University Press).
Mednick, S. (1962), 'The associative basis of creative processes', *Psychological Review*, **69**, pp. 220–32.
Mendelsohn, G. (1976), 'Associative and attentional processes in creative performance', *Journal of Personality*, **44**, pp. 341–69.
Millgram, E. (1997), 'Deciding to desire', in *Practical Induction* (Cambridge, MA: Harvard University Press).
Milner, P. (1957), 'The cell assembly: Mk. II', *Psychological Review*, **64**, pp. 242–52.
Milner, P. (1999), *The Autonomous Brain* (London: Lawrence Erlbaum).
Nagel, T. (1979), 'What is it like to be a bat?', in *Mortal Questions* (Cambridge: Cambridge University Press).
Norman, D.A., & Shallice, T. (1986), 'Attention to action: Willed and automatic control of behavior', in *Consciousness and Self-regulation*, ed. R.J. Davidson, G.E. Schwartz, & D. Shapiro, Vol. 4 (New York: Plenum).
Nudo, R.J., Milliken, G.W., Jenkins, W.M., & Merzenich, M.M. (1996), 'Use-dependent alterations of movement representations in primary motor cortex of adult squirrel monkeys,' *Journal of Neuroscience*, **16**, pp. 785–807.
Orbach, J. (1998), 'Hebb's organization of behavior 50 years after publication', in *The Neuropsychological Theories of Lashley and Hebb*, ed. J. Orbach (New York: University Press of America).
Palm, G. (1982), *Neural Assemblies: An Alternative Approach to Artificial Intelligence* (Berlin: Springer-Verlag).
Peterson, S., vanMier, H. Fiez, J., and Raichle, M. (1998), 'The effects of practice on the functional anatomy of task performance', *Proceedings of the National Academy of Sciences of the United States of America*, **95**, pp. 853–60.
Pettigrew, J. (1974), 'The effect of visual experience on the development of stimulus specificity by kitten cortical neurons,' *Journal of Physiology*, **237**, pp. 49–74.
Pigarev, I., Northdurft, H., and Kastner, S. (1997),'Evidence for asynchronous development of sleep in cortical areas', *Neuroreport*, **8**, 2557–60.
Poincaré, H. ([1902/1904/1908] 1982), *Science and Hypothesis: The Value of Science, Science and Method* , repr. in *The Foundations of Science* (Washington, DC: University Press of America).
Posner, M. (1978), *Chronometric Explorations of Mind* (Hillsdale, NJ: Erlbaum).
Posner, M. and P. Bourke (1996), 'Attention', in *The Blackwell Dictionary of Neuropsychology*, ed. J. Beaumont, P. Kenaealy, and M. Rogers (Oxford: Blackwell).
Posner, M. and Raichle, M. (1994), *Images of Mind* (New York: Scientific American Library).
Posner, M., DeGirolamo, G., and Fernandez-Duque, D. (1997), 'Brain mechanisms of cognitive skills', *Cognition*, **6**, pp. 267–90.
Rosenblatt, R. (1961), *Principles of Neurodynamics: Perceptrons and the Theory of Brain Mechanisms* (Washington D.C., Spartan Books).

Rumelhart, D., Hinton, G., and McClelland, J. (1986), 'A general framework for parallel distributed Processing', in *Parallel Distributed Processing: Explorations in the Microstructure of Cognition*, ed. D. Rumelhart, and J. McClelland, Vol. 1 (Cambridge, MA: MIT Press).

Seung, H.S. (2000), 'Half a century of Hebb', *Nature Neuroscience*, **3**, p. 1166.

Simonton, D. (1999), *Origins of Genius* (Oxford: Oxford University Press).

Smith, S. and Blankenship, S. (1989), 'Incubation effects', *Bulletin of the Psychonomic Society*, **27**, pp. 311–14.

Smith, S. and Blankenship, S. (1991), 'Incubation and the persistence of fixation in problem solving', *American Journal of Psychology*, **104**, pp. 61–87.

Smith, S., Ward, T.B. and Finke, R. (ed. 1995), *The Creative Cognition Approach* (Cambridge, MA: MIT Press).

Umilta, C. (2001), 'Mechanisms of attention', in *The Handbook of Cognitive Neuropsychology*, ed. B. Rapp (Philadelphia, PA: Psychology Press-Taylor & Francis).

Von der Malsburg, C. (1973), 'Self-organization of orientation sensitive cells in striate cortex', *Kybernetick*, **14**, pp. 85–100.

Wallas, G. (1926), *The Art of Thought* (New York: Harcourt, Brace, and World).

Weisberg, R. (1986), *Creativity: Genius and Other Myths* (New York: W.H. Freeman).

Weisberg, R. (1995), 'Case studies in creative thinking: Reproduction versus restructuring in the real world', in *The Creative Cognition Approach*, ed. S. Smith, T.B. Ward, and R. Finke (Cambridge, MA: MIT Press).

Weisberg, R. (1999), 'Creativity and knowledge: A challenge to theories', in *Handbook of Creativity*, ed. R. Sternberg (Cambridge, MA: Cambridge University Press).

Williams, B. (1973), 'Deciding to believe', in *The Problems of the Self* (Cambridge, MA: University Press).

Willshaw, D.J. (1981), 'Holography, associative memory, and inductive generalization', in *Parallel Models of Associative Memory*, ed. G.E. Hinton and J.A. Anderson (Hillsdale, NJ: Lawrence Earlbaum Associates).

Woodworth, R. and Schlosberg, H. (1954), *Experimental Psychology* (New York: Holt, Rinehart, and Winston).

Young, J.Z. (1951), 'Ferrier Lectures', *Proceedings of the Royal Society of London, Series B, Biological Sciences*, **139**, pp. 18.

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