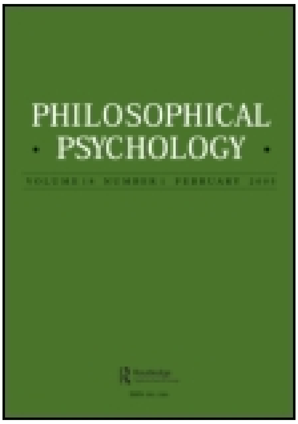

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Creative action in mind

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Creative action in mind

Peter Carruthers

The goal of this article is to display the attractiveness of a novel account of the place of creativity in the human mind. This is designed to supplement (and perhaps replace) the widespread assumption that creativity is thought-based, involving novel combinations of concepts to form creative thoughts, with the creativity of action being parasitic upon prior creative thinking. According to the proposed account, an additional (or perhaps alternative) locus of creativity lies in the assembly and activation of action-schemata, with creative thoughts arising subsequently from the mental rehearsal of those actions, normally resulting in either visual imagery or inner speech.

Keywords: Action; Creativity; Mental Rehearsal

1. Introduction

The topic of creativity has been heavily studied in recent decades, especially by researchers in the fields of psychology, business, and education. Most of this work has concerned the personality and other characteristics (such as extensive background knowledge) distinctive of especially creative individuals, together with the social and developmental circumstances and interventions that encourage creativity. Comparatively little work has been done on the cognitive foundations and sources of creativity itself (although some will be mentioned shortly). It is this that forms the topic of the present article.

Most researchers in the field share a similar understanding of what creativity *is*. (See, for example, the papers contained in Sternberg, Grigorenko, & Singer, 2004.) Creatively-produced outcomes are conceived to be novel (original, unexpected), high in quality, and/or appropriate (useful, meeting task constraints). But within this general understanding it is important to draw a number of further distinctions. The first is between what Boden (2004) calls ‘‘psychological creativity,’’ on the one hand (whose outcomes are novel from the perspective of the creator), and ‘‘historical creativity,’’ on the other (where outcomes are new from the perspective of an entire society or historical tradition). This distinction is drawn in terms of different kinds of

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novelty (new for the individual versus new for the group). But one might, instead, draw a distinction among different forms of psychological and historical creativity by focusing on the question whether it is the *value* or *appropriateness* of the creative outcome that is relative to an individual, on the one hand, or judged from the perspective of an entire society or tradition, on the other.

This then gives us three possible kinds of psychological creativity (individually novel, individually valuable/appropriate, or both novel *and* valuable/appropriate from the perspective of a single individual) together with three corresponding kinds of historical creativity. Our main focus will be on the processes underlying the various forms of psychological creativity. These are more fundamental (at least in respect of the novelty component), since any historically novel outcome must either be psychologically new or be the descendant of one or more prior psychologically novel outcomes.

A second important set of distinctions is between creative *products*, creative *actions*, and creative *thoughts* or *ideas*. The outcome of a creative process can be an object (whether concrete or abstract), like a new tool or type of tool, a new management practice, a new painting, or a new piece of music. But a creative outcome can also be an action or type of action, like a novel sequence of movements in free dance or a new way of using an existing tool. The outcome of a creative process can also be an idea or thought. The set of creative *actions* is wider than the set of creative *products*, since any novel (and valuable) object must be brought about by an action or sequence of actions that is creative (at least when described as the act of bringing about just such a product), whereas some creative actions don't issue in new objects.[1]

Only rarely will a creative product be the result of a single creative action, however. Many different actions will normally be needed in the construction of a new painting or piece of music, for example. And note that the *creativity* of a complex product will often be distributed across many different creative actions, as well. For it is rare for someone to have a complete idea of the object-to-be-created fully in mind at the outset, and it is equally rare for just a single property to account for whatever renders the new object creative. It is also reasonable to assume that where a complex object like a new theorem or new type of artifact is produced collaboratively by more than one agent, the respects in which the object is novel can in principle be factored into the different contributions made by the actions of the various agents involved. Our focus in this article will be on micro-creativity, so to speak: on the individual creative thoughts and actions which when combined may give rise to a creative product.

Moreover, just as the set of creative actions is wider than that of creative products, so it is natural to assume, likewise, that the set of creative *thoughts* must be wider than the set of creative *actions*. For one might expect that any intentionally-undertaken creative action would be preceded and guided by a creative thought (but not vice versa).[2] This assumption will be challenged in what follows. But note, at this point, that the assumption isn't necessarily supported by the fact that someone creating a novel product will generally have at least some idea of the desired endpoint before undertaking any overt actions. Although this shows that a creative thought occurs prior to creative overt action in such cases, it may nevertheless be the case that the thought, in turn, results from the covert mental rehearsal of a creative action of some sort, as we will see in due course.

Just as the nature of creativity is widely agreed upon by scientific researchers, so there is an emerging consensus that the creative process itself is a *constrained stochastic* one. One reason for thinking that creativity contains an element of randomness is that the most successful computer programs charged with generating novel products do so too (Boden, 2004). The same point can be made from the increasing use that is being made of genetic algorithms for discovery of solutions to complex problems, since these (like evolution itself) involve an element of random recombination (Mitchell, 1996). But in each case discovery isn't *purely* random, of course. On the contrary, the stochastic component needs to be heavily constrained, or guided by the use of search heuristics of one sort or another.[3]

Evidence that human creativity is underwritten by a constrained stochastic process can also be gleaned from patterns of public success and failure in a given domain. In his extensive studies of creative contributions to science, for example (however that is measured: whether by citation counts, prizes and other awards, and so on), Simonton (1999, 2003) shows that the overall patterning is exactly what one would expect to find if scientific creativity were a matter of random recombination within the constraints provided by existing knowledge, theories, skills, and so forth. For the most productive individuals over a lifetime tend to have the most successes, but also the most failures. And likewise within a single career the greatest number of successes and failures will be found within periods of greatest productivity. Moreover, although scientists differ in their ratios of successes to failures (some are more perfectionist, some less so), this does nothing to undermine the basic picture that emerges of constrained randomness, Simonton argues. In what follows I shall assume, along with Simonton and others, that creativity results from some sort of constrained stochastic process.

There is a great deal more to creativity than constrained stochasticity, of course. Any stochastically produced item needs to be recognized and evaluated before it can be either psychologically or socially valuable. Moreover, if the item in question is an idea of some sort, then much may need to happen in the way of implementation, drawing on both the knowledge and skills of the agent, before that idea can be realized in a creative action or creative product. My focus in this paper, however, is on the locus, or loci, of stochastic generation within the architecture of the human mind (together with the format of the representations involved). While stochastic generation isn't creative by itself, it would seem to be a necessary condition of creativity. And it appears to be separable from the processes of evaluation and implementation that occur subsequently (although, as noted earlier, each of these might involve further stochastically generated elements). The focus of this article is on the nature of the stochastic processes that issue in novelty, not on the subsequent processes of evaluation, acceptance, or implementation, important as these no doubt are. For I presume that the cognitive processes involved in the latter aren't exclusive to creative forms of cognition, but are rather much more general. It is stochastic generativity that is *distinctive* of creativity.

One might be tempted to think that the claim that creativity is underwritten by some sort of constrained stochastic process is inconsistent with the idea—which is surely very plausible—that many forms of creativity are *associative*, resulting from associative connections among concepts. Consider metaphor, for example. Creative metaphors will often depend upon seeing some sort of association between the concepts involved (or between their instances). But there need be no inconsistency here. For there will always be more than one concept (often a great many more) associatively connected with a given concept. So the mechanism that selects one of them to be formulated into a metaphor can be partly stochastic. Indeed, it is plain that metaphor can't result from any simple deterministic rule like, "always select the most co-activated concept," or there would never be any such thing as *creative* metaphor. Creative metaphors are generally surprising and unexpected, while being illuminating when understood. Consider the person who created the now-familiar metaphor: "argument is war," for example. There will, of course, have been many more concepts more strongly associated with his argument-concept than was his war-concept. Hence the mechanism that picked out the latter might have been stochastically selecting and "trying out" various of the associatively-activated candidates.

I noted earlier that it is natural to think that creative actions must be preceded by creative thoughts. Call this the "thought-first" theory of creative cognition. On this account there is just a single locus of creativity within the human mind, which lies in a mechanism that can assemble and combine concepts in novel ways. These creative thoughts can then issue in novel actions, or they can be entertained as suppositions to be explored and evaluated by other faculties of the mind, just as so-called "Geneplore" (for "generate and explore") models of human creativity suggest (Finke, 1995; Finke, Ward, & Smith, 1992; Ward, Smith, & Finke, 1999). Indeed, a thought-first account is assumed, either tacitly or explicitly, by almost everyone who writes on the topic of creativity. One reason for this lies in the truism that thought generally precedes action. We often plan before we act, and common sense assumes that we *always* act in light of our prior beliefs and goals. So the latter must have been created first. It can therefore appear puzzling how creative actions could be generated except by first engaging in creative thought. Even more puzzling is how creative *thought* could instead be *action-based*. (Call this an "act-first" account.) How *could* creative thought be caused by prior creative action?

One of the aims of the present article is to dispel these sources of puzzlement. Section 2 will explain how recent discoveries in cognitive science can be used to show how actions can be controlled and initiated directly, without being caused by prior conceptual thought. This will open up at least the possibility that creative actions might be produced in the absence of creative thought. Then section 3 will argue that an act-first theory is at least possible, showing how creative thoughts might issue from the activation and mental rehearsal of creatively generated action-schemata. Sections 4 and 5 will then argue that it isn't just *possible* that creative action should be undertaken in the absence of prior thought, but *actual*. For example, creative actions undertaken during jazz improvisation or in free dance are unlikely to be preceded by prior creative thoughts. If so, then a thought-first account cannot be *generally* true.

At this point in the argument it would remain possible, of course, that neither a thought-first nor an act-first account is exclusively correct, and that there is more than one locus of stochastic generativity within the human mind. It may be that some creative outcomes (whether objects or actions) have their origins in creative thought, whereas others (whether objects or thoughts) have their origins in creative action. It is worth exploring, however, to what extent creativity is *exclusively* act-first. One reason for this is that act-first accounts are almost invisible in the literature. Until recently they have had, to the best of my knowledge, precisely zero adherents (although Miller [1997] comes close). Moreover their only existing defender is the present author (Carruthers, 2006, 2007). Since act-first accounts have barely been discussed or evaluated previously, it remains an entirely open question how broad their range of application might be. It is worth considering, therefore, how far one can push the idea that human creativity is exclusively act-first. Sections 6 through 8 will make some first tentative steps in that direction.

Before we begin to consider the evidence, however, more needs to be said about the contrast between thought-first and act-first accounts, as well as to distinguish the latter from other similar-sounding views in cognitive science. An initial problem is that action-schemata are *representations* of motor sequences, and they may well be constructed from combinations of concept-like representations of static postures of the body and limbs (Rosenbaum, Meulenbroek, Vaughan, & Jansen, 2001; Wolpert & Flanagan, 2001); so they appear to be thought-like. Likewise, many paradigmatic conceptual thoughts are thoughts *about action*, of course. Hence we cannot distinguish between the two sorts of representation in terms of their subject-matter. Nevertheless, conceptual thought processes and action-schemata appear to have distinct neural realizations and to differ significantly in their functional roles (Milner & Goodale, 1995). Roughly speaking, the former are realized in the temporal and frontal lobes and give rise to semantic or episodic memories. The latter, in contrast, are realized in motor, premotor, and supplementary motor areas of cortex together with the parietal lobes, and are stored in a separate motor-skill memory system (Jeannerod, 2006; Rosenbaum, 2010). It is in these terms that the distinction between thought-first and act-first accounts should be understood in the discussion that follows.

It is also important to distinguish an act-first account from so-called "embodied cognition" approaches to cognitive science (Barsalou, 1999; Gallese & Lakoff, 2005). In part this is because the act-first thesis is a highly restricted claim, pertaining only to the sources of stochastic generativity in particular. But it is also because an act-first account presupposes that strong forms of embodied-cognition thesis are false. According to the latter, concepts are *constituted* by sensorimotor representations. If this were so, then it would make no sense to ask whether the locus of generativity lies in the conceptual or rather the motor aspects of the mind. In what follows, therefore, while acknowledging that conceptual systems and motor systems interact at many different levels, I shall assume that the two can in principle be distinguished.[4]

We can then ask whether processes of constrained stochastic generation are located in former, or in the latter, or in both.

It is important to notice, too, that the generativity of natural language is quite different from the sort of constrained stochastic generativity that forms our target (even if the former partly subserves the latter). The sense in which language is generative is that its components admit of unlimitedly many structured combinations and re-combinations. But it is one thing to have a *capacity* to generate novel combinations, and it is quite another thing to use it; and it is another thing again to use it in a constrained stochastic manner. That will require some separate cognitive basis (either thought-first, or act-first, or both). Hence creativity doesn't come "for free" with a capacity for natural language.

In summary, then, the focus of this article is on the locus within the human mind of the generative aspect of creative cognition (as well as the format of the representations involved). Is the source of creativity located in thought, stochastically assembling novel conceptual representations? Or is it located in our motor systems, pulling together and activating novel action schemata? Or are there perhaps two distinct loci, one of each kind? I shall argue that we have good reasons to rule out the first, exclusively thought-based account. I shall also present some considerations that might support the second, exclusively act-based view. Both sets of arguments are admittedly inconclusive (although the former are stronger than the latter). Much remains to be investigated.

2. Action without Thought

We noted earlier that a thought-first account of the locus of creativity is supported by common sense views of the priority of thought over action. This consideration is far from decisive, however. For we know for sure that action can at least be *controlled* in ways that bypass anything resembling thought and conceptualized planning, and there is good reason to think that actions can be *selected* and *initiated* independently of thought as well. So it isn't the case that thought always precedes action. Let me briefly defend each of these claims in turn.

We now know that the human visual system bifurcates into two functionally distinct (albeit interacting) streams of processing: a what/where system located in the temporal lobes, and an action guiding (or "how to") system in the parietal lobes (Jacob & Jeannerod, 2003; Milner & Goodale, 1995). The former situates and identifies objects and events, and broadcasts its outputs to a wide range of conceptual systems for drawing inferences, for practical reasoning, and for forming memories and motivations. The latter, in contrast, represents target objects nonconceptually in body-centered or limb-centered spatial coordinates for purposes of on-line control of action. Using this system, subjects can adjust their actions to changes in the target object that they never consciously perceive (Bridgeman, Kirch, & Sperling, 1981; Goodale, Pélisson, & Prablanc, 1986). And patients with temporal lobe damage, who are incapable of conscious vision and are at chance in their perceptual judgments, can nevertheless orient their hands appropriately to post a letter through a variably-oriented letter-box, and can reach for and grasp objects of varying sizes normally, using an appropriate finger grip (Milner & Goodale, 1995). Indeed, one of the things that originally led to the discovery of the so-called "blindsight" phenomenon was the observation that patients with damage to primary visual cortex, who are apparently blind in respect of some or all of the visual field, are nonetheless able to avoid "unseen" obstacles when walking through a crowded room (Weiskrantz, 1997).

Not only can action be guided and controlled in the absence of conceptual thought, but it can also be initiated without such thought. One instance of this is provided by automatic "mirroring" behavior in social situations. As is familiar, yawning and smiling tend to be contagious. But this also extends to more complex behaviors and sequences of behavior which would normally be considered voluntary. When two people are engaged in conversation, for example, both will tend to adopt the same bodily postures and mannerisms, and if one leans back in his chair with hands clasped behind his head, the other will be apt to do so too (Jeannerod, 2006). Moreover, the evidence suggests that such mimicry would be a great deal more widespread were it not for the inhibitory effects of the frontal lobes. For patients with certain kinds of frontal damage will compulsively imitate the actions of others (Jacob & Jeannerod, 2003).[5]

Indeed, the evidence suggests that in normal people action schemata are *activated* without prior thought on a routine basis, although the actions themselves don't get executed because of inhibition from frontal executive systems. In addition to automatic activation of action schemata that mirror the observed actions of others, observation of object affordances (such as the "to be grasped" shape of a hammer, handle of a cup, and so forth) will cause activation of the schemata for appropriate grasping movements. Object affordances are processed within a special subsystem of parietal visual cortex, which operates independently of conceptualization and awareness, and which passes on its output to motor and premotor cortex (Jacob & Jeannerod, 2003). And in this case, too, we find frontal patients who engage in compulsive *utilization* behavior, where the mere sight of an object with a familiar affordance (a hammer, say) is sufficient to initiate the appropriate grasping action (Lhermitte, 1983, 1986; Shallice, Burgess, Schon, & Baxter, 1989). It therefore appears that prior thought (or at least inhibition) is required in order for actions of these kinds *not* to be executed, rather than for their action schemata to be assembled and activated in the first place.[6]

I have been arguing that not all action is preceded by prior thought. (Further arguments for this conclusion, but targeted more specifically on *creative* action, will be provided in sections 4 and 5.) But it is also true, as I shall shortly show, that action-schema activation *can* give rise to *subsequent* thought. Indeed, I shall demonstrate in section 3 that the air of mystery that attaches to an act-first account is easily dissipated, and that the latter makes perfectly good sense in light of recent discoveries in cognitive science. This should be sufficient to undermine the presumption in favor of a thought-first theory of creativity.

3. How Actions can Cause Thoughts

According to the act-first account, action schemata can be activated and assembled creatively (in a constrained stochastic manner) without the assemblage being guided by prior creative thoughts or intentions. When this happens the resulting action schema is either implemented in action immediately (see sections 4 and 5), or it can be mentally rehearsed, issuing in imagery of the represented action. These images can be visual, or they can be auditory (especially in the case of so-called "inner speech"), or they can be proprioceptive (in the form of so-called "motor imagery"). The images in question are "globally broadcast" and conceptualized by the full range of conceptual systems, just as the equivalent perceptual contents would be if attended to, thereby becoming conscious. And the result is that one or more novel thought contents get presented to our inferential and decision making systems for elaboration and evaluation.

The use of mental rehearsals of action during decision making is now quite well established (Damasio, 1994, 2003; Gilbert & Wilson, 2007). When considering a plan of action we frequently rehearse it in imagination. The resulting imagery is received as input by our various motivational and emotional systems, which respond accordingly (e.g., our spirits lift or our hearts sink). We monitor the resulting bodily/affective gestalt, with the result that motivation towards the envisaged action is adjusted up or down. So these are cases in which the activation and rehearsal of a motor plan gives rise to a conscious imagistic thought of the action in question for purposes of evaluation. The same thing also frequently happens, of course, in respect of *speech* actions. An action schema for a particular utterance can be activated and rehearsed, issuing in auditory imagery of the likely result of that action, in "inner speech." The latter is processed and interpreted by the language comprehension system in the normal way, giving rise to a consciously experienced verbal *thought*, much as if one had heard someone else speak. This can then be reflected on and evaluated.

Many of the cognitive components involved in action rehearsal are quite ancient and are present in other animal species.[7] As has already been noted, the divergence between temporal lobe and parietal lobe visual systems is now well established and appears common to all mammals. Moreover, a similar distinction is thought to exist within other sense modalities (Michel & Peronnet, 1980; Paillard, Michel, & Stelmach, 1983; Rossetti, Rode, & Boissson, 1995). Likewise the "global broadcast" of attended perceptual information in the brain and its coincidence with consciousness is now widely accepted (Baars, 2002; Baars, Ramsoy, & Laureys, 2003; Dehaene & Naccache, 2001; Dehaene, Sergent, & Changeux, 2003), as is the fact that imagery, too, shares mechanisms with perception and attains conscious status in exactly the same manner (Kosslyn, 1994). Moreover, we also know that there are back-projecting pathways in the parietal visual system that exist to monitor and fine-tune the on-line guidance of action (Wolpert & Flanagan, 2001; Wolpert & Ghahramani, 2000; Wolpert, Doya, & Kawato, 2003). When motor schemata are activated, not only are commands sent to the muscles necessary to control the intended action, but "efference copies" of those commands are also created and used to generate a representation of the expected consequences of executing the action, called a "forward model." The predicted sequence is then compared with the actual sensory input received, and detailed adjustments in the execution of the action can be made accordingly, as the action unfolds.

Although forward models of action are normally deployed within parietal lobe systems in their interactions with motor cortex, and remain unconscious, they can also be used to create conscious images within the temporal lobe system. For the two systems are significantly connected with one another via a region of tempero-parietal cortex, which is probably best thought of as a common functional component of each, and which forms part of the "mirror neuron" system (Gallese, Fadiga, Fogassi, & Rizzolatti, 1996; Rizzolatti, Fogassi, & Gallese, 2000).[8] As a bridge between the temporal and parietal visual systems, this part of the mirror neuron system is well placed to map conceptual representations of the actions of another person, categorized within the temporal system, onto corresponding motor schemata of the appropriate type, via the parietal system's intimate connections with motor cortex. This enables imitation of the other person's actions to occur. But the mirror neuron bridge is also well placed to map one's own actual or supposed movements into the temporal lobe system, giving rise to globally broadcast visual representations of those movements and their immediate consequences.

It is also possible to entertain conscious imagery of things other than one's own rehearsed actions, of course. Conceptual representations of objects and events can utilize back-projecting pathways within the temporal lobe system (which are normally employed to assist with object recognition; Kosslyn, 1994) to generate perceptual representations that can then be processed by the visual system and globally broadcast in the normal way. It is important to note, however, that the *transformation* and *movement* of such images appears to be heavily dependent upon the activity of motor cortex (Ganis, Keenan, Kosslyn, & Pascual-Leone, 2000; Kosslyn, 1994; Kosslyn, Thompson, Wraga, & Alpert, 2001; Lamm, Windtschberger, Leodolter, Moser, & Bauer, 2001; Richter et al., 2000; Turnbull, Carey, & McCarthy, 1997). If it turns out, therefore, that action schemata can be assembled and utilized creatively, then the result can be creative combinations and transformations of images of familiar objects.

An act-first account of creativity should no longer appear mysterious. For not only can action representations be activated independently of prior thought and planning (as we saw in section 2), but such representations can be mentally rehearsed in such a way as to give rise to conscious imagery of the action in question, thus issuing in thought. In which case, if action-schemata can be assembled and activated creatively independently of prior creative thought, then creative action will be capable of issuing in creative thought, just as an act-first account proposes. Sections 4 and 5 will provide reasons for thinking that creative action-assembly does indeed sometimes occur, and that the capacity for it may be of ancient evolutionary ancestry.

4. On-Line Creative Action

The present section argues that a thought-first account of the locus of creativity isn't generally applicable, and that sometimes, at least, creativity results from the constrained stochastic assembly and activation of novel action schemata, in the absence of prior creative thought.

Consider examples of swift on-line creative action, such as can occur in jazz or organ improvisation, or extemporized movements in free dance. In such cases it is implausible that each creative action should have been preceded by a creative thought, since it seems unlikely that there would have been time for this to happen. For consider just how *fast* creative actions can be. (Similar points will apply to dance, and also to some forms of speech and some kinds of athletic performance.) A jazz improviser can be playing at full speed, piecing together and recombining previously rehearsed phrases and patterns, when he suddenly finds himself playing a sequence of notes that he has never played before, and which surprises him (Berliner, 1994). Charlie Parker, for example, could play his improvised solos at amazing rates, some of them at speeds of 400 notes per minute (Owens, 1995). Most of us would have trouble even tapping our feet to such a tempo. And even though his solos were mostly composed of arrangements and re-arrangements of formulaic fragments ranging from two or three note patterns to clusters of a dozen notes, it is difficult to believe that there was time in which to form a conceptual but fully detailed representation of each such fragment in advance of activating the motor schema for it. For compare the speed of neural transmission. It takes about a tenth of a second for a signal to pass down an axon just ten centimeters long, not allowing for the time required for electronic spread along the dendrites or for synaptic transmission.[9] In contrast, it appears that Charlie Parker was capable of creatively activating and executing at least one complete action schema every second or half second (depending on the length of the well-rehearsed phrase in question).

Moreover, reflect on the implications of the point noted in passing above, that jazz improvisers are often surprised by their own products. (Again, a similar argument could be constructed in respect of some instances of dance or speech.) This is direct evidence in support of the view being proposed here, that actions can be creative without prior creative thought. For surprise is the emotion that we feel when something *unexpected* happens. The expectations in question don't have to be consciously entertained, of course. On the contrary, events can be most surprising when they violate tacit expectations that it would never have occurred to us to formulate consciously otherwise. So when a jazz improviser is surprised by the sequence of notes that he hears himself play, this is evidence that he didn't have a prior expectation (whether conscious or unconscious) that he would play a sequence of notes of that sort. And that means that he had *not* formulated a creative thought in advance of performing the creative action.

It might be objected that a thought-first theorist can accommodate the jazz improviser's surprise by appealing to the constrained stochastic character of creativity. For if the initial thought about what sequence of notes to play next were put together in a stochastic manner, then that thought might well violate the improviser's background expectations about what sorts of sequences are likely to come next, issuing in surprise. However, the improviser isn't surprised by what he *thinks* but by what he *does*, or by what he hears himself play. And since (by hypothesis) he had just formulated an occurrent thought that he should play the sequence of notes in question he should *not* be surprised when he hears them. For those are precisely the notes that he had just decided to play. This might lead him to recognize that he has produced something novel and (because valuable) creative, perhaps; but it should not issue in *surprise*.

In addition, the dimensions of creativity that can be involved in on-line creative action aren't limited to the choice of actions and action components, grossly conceived. They also include the precise manner in which these actions are executed, such as the exact timing and timbre of a note or musical phrase, or the precise orientations of body, limbs, and fingers at a particular moment during a dance. These things, too, can be both novel and valuable, while being done for the first time "in the moment." Yet it is implausible that the agents involved should possess concepts with this degree of fineness of grain. Indeed, just as the precise shades of color in a rose petal have a richness and fineness of detail that escapes conceptual description (Carruthers, 2000; Kelly, 2001), so it seems that action, too, has a partially nonconceptual character. And then whatever determines the creative selection of such details cannot be prior conceptual thought and planning.

These considerations appear to show that a thought-first account of the locus of creativity cannot be *generally* true, thus establishing that there are at least some domains in which an act-first account applies. However, the arguments of this section cannot be considered conclusive. This is because a thought-first theorist *could* insist that even Charlie Parker was really entertaining a stream of unconscious creative thinking and planning, running just ahead of, and serving as the primary cause of, his improvisations, in complete detail. Without further evidence of an upper limit on the speed with which thinking can take place, or of how fine-grained conceptual thought can be, it is hard to rule out such a proposal decisively, unlikely as it seems. Moreover, Parker's occasional surprise at his own improvisations could perhaps be explained (albeit not very plausibly) by postulating that his swiftly formulated thoughts and expectations were somehow rendered inaccessible to the rest of his cognitive system (and in particular, inaccessible to subsequent perceptual input of the results of his own actions). What we do now possess, however, is one good (although admittedly inconclusive) reason for embracing an act-first account of creativity, at least within a limited domain of application.

5. Stochastic Action-Generation in Animals

The present section argues that capacities for creative action-generation are quite widespread in the animal kingdom, in the absence of any capacity for prior creative thought. In each case the actions are psychologically but often not historically novel ones, and are valuable and appropriate at least from the perspective on the animals concerned. This gives us a further reason for denying that a thought-first account of creativity can be generally correct. But it will also provide the premise of an evolutionary argument in support of an exclusively act-first account (to be presented in section 7).

Some might baulk at describing the actions of a moth, or a rabbit, or a bird as "creative." This could be because of a belief that only historically creative actions are genuinely deserving of the term; or it might be because it is held that psychologically valuable actions need to be intentional *under that description* in order to count as creative. I don't need to argue the point. For recall that my focus is on the generative component in creativity. This might have a long evolutionary history (as I argue here) even if creativity itself doesn't. It may be that what happened in the course of hominid evolution, for example, is that a pre-existing capacity for constrained stochastic action-schema assembly was exapted and used for novel purposes, such as creative mental rehearsals of action while problem solving.

Three considerations suggest that a capacity for stochastic action selection might have formed part of our evolutionary heritage. One is that so-called "protean" behavior is quite widespread in the animal kingdom, especially when escaping from a predator (Driver & Humphries, 1988; Miller, 1997). A moth that detects bat ultrasound, for example, will go into a looping, tumbling, flight pattern that seems genuinely random, thereby making its movements unpredictable to the pursuing bat. The same is true of the leaps and bounds and changes of direction of a gazelle being chased by a lion or a rabbit being chased by a wolf (or a human athlete, indeed, attempting to avoid an opponent in any contact sport such as rugby or American football). Such protean behavior is much more effective than a straight escape path or any sort of planned exit. For the best way to make yourself unpredictable to others is to behave in a way that is actually random.[10]

Note that even here, however, randomness occurs within constraints: it is the actions involved in locomotion and changes of direction that are stochastically combined and recombined, not actions from the animal's repertoire in general. An escaping rabbit, for example, won't also twitch its ears or wiggle its tail in a random manner, let alone attempt to do so in place of its evasive leaps and bounds. Moreover, it is highly implausible to think that moths and rabbits are engaged in creative thinking and planning in advance of their protean behaviors. Indeed, a moth might not be capable of thinking at all, and rabbits may well be incapable of thinking about their own actions, even if they are capable of thinking about other things.[11] Rather than making stochastic selections from among a relevant set of concepts and acting accordingly, it is much more plausible to think that animals are making random selections from among the relevant set of action schemata *directly*.

A second source of evidence derives from the study of the songs of some species of bird and whale. While many forms of birdsong are highly stereotyped, and are either innate or learned from adults of the same species, others vary widely from individual to individual and from occasion to occasion. This is especially true of the pied butcherbird of Australia, which combines and recombines song fragments in novel ways, with multiple analogies to human music (Taylor, 2008a, 2008b). Likewise, the songs of humpback whales change and evolve rapidly over time in a way that suggests improvisation and subsequent imitation (Payne, 2000). Such capacities may be explicable in terms of evolution by sexual selection, given that most species of animal show an interest in *novelty*, paying greater attention to novel than to familiar phenomena; and similar capacities may have emerged at some point in the hominid lineage (Miller, 1997). But in the animal cases, at least, it is implausible to think that creative song-construction must result from prior creative thinking.

A final indicator that a capacity for stochastic action-selection would have existed prior to the evolution of a capacity for creative thinking is that some of our best models of action imply that selections are made randomly whenever there are options that are roughly equivalent in terms of ease of implementation. On the account developed and experimentally investigated by Rosenbaum and colleagues, for example (Rosenbaum et al., 2001; Rosenbaum, Vaughan, Meulenbroek, Jax, & Cohen, 2008), movement choice is determined within a hierarchically arranged series of constraints, which vary from task to task and from context to context. Representations of recently adopted postures and movements are examined against the constraint hierarchy (probably in parallel), first eliminating those that fail to satisfy the most important constraint, then those that fail the next most important, and so on. Especially significant for our purposes, if more than one candidate satisfies all constraints then the selection is made at random.

Rosenbaum et al. (2008) suggest that this aspect of their model can explain trial and error learning, since choices that are initially made randomly can be found to have unexpected benefits, leading to a new constraint being added to the constraint hierarchy for future use. (Note that in such cases the action can count as psychologically creative, since it is both novel and valuable from the perspective of the agent.) Moreover, while the model is designed as an account of the processes involved in human action selection, there is no reason to believe that it contains anything that is *distinctively* human. Indeed, the problem-solving behavior of many species of monkey fits the model remarkably well. Monkeys attempting to retrieve an item of food from a human device, for example, will swiftly combine and recombine actions from their repertoire that match the affordances of the object in a seemingly random and thoughtless manner until a solution is hit upon.

It appears, therefore, that constrained stochastic action selection has a long ancestry, being present in many other animal species. Yet it is implausible that such capacities should somehow have been lost in the course of hominid evolution. Indeed, both the argument from on-line creative human action, given in section 4, and Rosenbaum's model of human action-selection cited above provide direct evidence to the contrary. So we have reinforced the case for saying that a thought-first account of creativity cannot be generally correct.

6. Creative Mental Rehearsal in Animals

While constrained stochastic action has a long ancestry, it would cohere especially well with the act-first account of creativity if we had reason to think that our closest animal relatives sometimes engage in creative mental rehearsal of action when problem solving, perhaps responding emotionally to imagined scenarios in the manner described by Damasio (1994). I shall discuss this in two stages, first examining data suggesting that apes may sometimes engage in mental rehearsals of action, then considering examples where such rehearsals would appear to be creative in character.

Mental rehearsal provides us with a plausible explanation of medium-term planning in apes. Consider the chimpanzees of the Congo basin, for example, who have been videotaped making regular visits to a number of different termite mounds over a wide area (Sanz, Morgan, & Gulick, 2004). In order to harvest from subterranean nests they use two kinds of tool in combination: a strong stick to puncture the mound, and then a frond to dip for termites through the hole that they have made. Chimpanzees were never observed arriving at a subterranean nest without the requisite tools, unless there was already a puncturing-stick at the site. (Dipping-fronds decay too quickly to be left at a site and re-used on a later visit. These were always carried on arrival.) But puncturing-sticks are always constructed from the same type of tree, and frequently the closest tree of that type is tens of meters away through the forest, from which point the termite mound isn't visible. So we can be confident that these are instances of advance planning. (See also Mulcahy & Call, 2006.)

How is such planning cognitively realized? A plausible account can be given in terms of mental rehearsal. While the chimpanzee travels she activates and rehearses the motor-schemata for the various action-sequences that are needed to reach termites in a subterranean nest, including the act of approaching the nest and puncturing it. This is transformed into a visual and/or motor image and globally broadcast, reminding her that she needs to have a puncturing-stick in her hand. That creates a novel sub-goal (to carry such a stick), which in turn initiates a search for the information and motor-schemata necessary to achieve it. Since she doesn't recall leaving a puncturing-stick at the nest site, but does recall the location of a nearby tree of the appropriate type, she now adjusts her direction of travel towards that.[12]

Turning now to the question of *creative* rehearsal in animals, there is certainly plenty of data that can be understood in a manner that is consistent with this suggestion. What I have in mind are many instances of one-off behavior in apes (especially chimpanzees) which were initially interpreted as displaying tactical deception, attempting to induce a false belief in the mind of another (Byrne & Whiten, 1988). For the evidence now suggests that although chimpanzees may be capable of thoughts about the behavior, perceptual access, and ignorance of others, they aren't capable of reasoning about beliefs and false beliefs (Hare, 2007; Kaminski, Call, & Tomasello, 2008; Krachun, Carpenter, Call, & Tomasello, 2009). In consequence, the data might be better explained by creative action rehearsal, as I shall briefly explain.

Consider an adolescent chimpanzee who is being pursued by an aggressive adult male. When she reaches the middle of a clearing she comes to an abrupt halt and pulls herself fully upright, gazing alertly into the bushes in the way that she might do had she spied a predator. When her pursuer, too, comes to a halt and follows her gaze, she is able to make her escape. How did she hit upon what appears to be a creative strategy? (Such behavior hadn't previously been observed in her troupe, yet is valuable from her own perspective.) As she ran she might have been desperately rehearsing actions from her repertoire (climbing a tree, screaming, and so on) with no hint of success. But when she rehearses the stopping-and-looking action schema, her social knowledge enables her to predict that the male will stop and look too, thereby providing her with the opportunity that she needs.

If these interpretations are correct, then they suggest not only that actions can be creatively generated in the absence of prior creative thought (as was argued in sections 4 and 5), but also that creatively generated action-schemata can be used to drive subsequent creative thought (in this case imagistic thoughts of an action drawn randomly from the animal's repertoire). This is our first tentative evidence in support of an act-*first* account of creativity.

7. An Evolutionary Argument

We have noted that there is reason to think that a capacity for creative action-schema selection and activation might pre-date the hominid line. In contrast, there would seem to be no evolutionary precursors of the sort of stochastic concept combination that would need to be postulated by a thought-first theorist. Belief formation and decision making can be *noisy* processes, to be sure, which introduces a stochastic element into cognition. But there is no evidence of processes in nonhuman animals that systematically exploit such noisiness. So it looks as if the postulated stochastic concept selector and thought generator would have to be built *ab initio*.

In contrast with the thought-first account, there *are* evolutionary precursors of stochastic action-schema activation of just the sort that the act-first account sees as lying at the basis of creative cognition, as we have seen. So there were resources already existing within the motor control systems of our ancestors, waiting to be exapted by evolution and used for the creative mental rehearsal of action (which would in turn enable humans to entertain creative thoughts, as we saw in section 3). The stochastic mechanisms involved in action selection, moreover, come with a set of constraints on randomness (or the capacity for such constraints) already built in. For action selection is normally only random within the framework imposed by an initial plan (Rosenbaum et al., 2008). There will therefore be ways of adjusting the constraints on the specification of the desired action (e.g., constraints involving permissible key transitions in music), while leaving action selection genuinely random within those constraints.

While the existence of creative action-rehearsal in animals is somewhat speculative, it is at least reasonable to assume that the evolution of a pair of inter-related dispositions might have been sufficient to issue in distinctively human creative cognition.[13] The first is a disposition to randomly select and activate action-schemata from higher up the action constraint hierarchy than normal (or alternatively, a disposition to weaken that hierarchy in certain circumstances in such a way that random selections will be made more often), either rehearsing or implementing the action in question. And the second is a disposition to engage in *frequent* mental rehearsals of action, resulting in the Joycean stream of inner speech and conscious visual and motor imagery that is so characteristic of our waking lives. (In contrast, it seems likely that creative rehearsal in animals is a matter of last resort.)

Such an account already appears sufficient to explain certain kinds of creative action, given that the initial constraints can be specified in such a way as to leave many potential candidates that satisfy the constraint hierarchy (thereby leading to random selections from among them). A jazz improviser might be characterized as operating under the constraint: "select at random from among well-practiced sequences of notes that are drawn from the following keys . . . ," for example. And someone improvising a dance might be said to be operating under the constraint: "select at random from among movements of the limbs and torso while keeping time with the tempo of the music." Moreover, the present account can explain the sense in which all speech is minimally creative. For given the extent of redundancy in the natural language lexicon (as well as the availability of nearly equivalent syntactic frames such as active versus passive constructions), speakers will almost always be making random selections among speech-act components that satisfy all constraints in the current constraint-hierarchy.

We therefore have in hand a plausible account of act-first creative cognition, starting with pre-existing capacities in animals for the creative selection and activation of action-schemata together with mechanisms enabling the mental rehearsal of action. These could quite easily have become enhanced and exapted in the course of hominid evolution to give rise to full-blown creative human cognition. Of course it doesn't follow from this account, even if correct, that all human creativity is of the act-first variety. For creativity may quickly have become so important within the life-histories of humans (for either problem-solving or mate-attraction or both) that a further locus of creative generativity was thereafter added within the thought-constructing regions of the mind.[14] If so, then although act-first forms of creativity may be evolutionarily prior, thought-first kinds might play an equally significant role in contemporary human cognition (if not more so). It is worth noting, however, that building a thought-based locus of creativity would by no means have been easy—or so I shall suggest. This will give us *some* reason to think that evolution might instead have opted to exapt, tinker with, and extend the reach of what it already had (an act-based locus), rather than build a completely new system *ab initio* as well.

It might be said that setting up thought-first forms of creativity wouldn't necessarily have been so difficult. In essence, one would only need to install some sort of random concept selector. But creative cognition isn't *simply* random, of course. Rather, the best characterization is in terms of randomness within constraints, as we have assumed throughout. So natural selection would have had to build, not just a mechanism that can make random selections among concepts, but also flexible ways of constraining the range of permissible selections. But it seems that the only existing resource that would have been available to impose such constraints would have been the circle of activations and co-activations among concepts. This doesn't have the required specificity, however. A jazz improviser, for example, may be operating under the constraint that all phrases should be selected from a pre-determined set of musical keys. However, phrases drawn from other keys may be equally co-activated if one relies only on previous associations. So the stochastic concept selector would have had to be built with some way of inserting a tailor-made set of constraints to screen out unwanted concept combinations in the particular circumstances in question. In contrast, the equivalent feature would already have been present in the motor control systems of our ancestors, as we have seen.

I conclude that evolutionary considerations can provide us with some reason to think that distinctively human forms of creative cognition were built by co-opting, exapting, and developing capacities for constrained stochastic action-schema activation and mental rehearsal that were already present in our animal ancestors. If so, then we have reason to think that creativity might be exclusively act-first in nature.

8. How Far can an Act-First Account be Extended?

At this point both an exclusively act-first account as well as some sort of mixed act-first/thought-first hybrid remain as live options, although the evolutionary considerations presented in section 7 have provided some reason to prefer the former. (Although our previous arguments weren't fully conclusive, I propose to assume, now, that they have taken any purely thought-first theory of creativity off the table.) For the reasons sketched in section 1, however, it is worth considering how far an act-first account of creativity can be taken. Can it explain phenomena traditionally characterized in thought-first terms, for example, like creative speech production and creative hypothesis generation?[15]

We have already noted how the simplest forms of linguistic creativity can be explained in act-first terms, through stochastic selections among equivalent vocabulary items and syntactic forms. To see how an act-first account might work in connection with other kinds of creative speech production (whether overt or inner), consider metaphor, and consider a case where the speaker already has a determinate message to be communicated.[16] Think of Romeo, who wants to communicate that Juliette is uniquely important to him. The constraint on action-schema activation that he employs might be only, "complete the sentence-frame 'Juliette is . . . ' with a word for something that is unique in its importance or value." (Alternatively he might employ: "complete the sentence-frame 'Juliette is . . . ' with any lexical item that is strongly associatively linked with one or more value-concepts.") Romeo then selects from among the available action-schemata randomly, issuing in "Juliette is the sun." If this were his only constraint, then Romeo would be well-advised to rehearse and self-monitor before speaking aloud, of course. For otherwise he might equally end up saying, "Juliette is a mother to me," which would give quite the wrong impression. But if Romeo is a practiced creative speaker then he may be able to impose additional constraints on the initial action selection, making it much more likely that he will hit upon a metaphor that is appropriate.

Many speech actions are undertaken or rehearsed without there being any particular message-to-be-communicated that has been determined in advance, of course. Rather, the agent has in mind some larger purpose that a speech-act of an appropriate kind would serve. (Think of meeting an old friend for the first time after a long interval, for example, and wanting to say something complimentary about the friend's appearance.) Included under this heading will be instances of creative hypothesis formation in both science and everyday life. In such cases the agent wants to produce a sentence of a particular sort, namely one that will serve to explain whatever puzzling phenomena are in question (or that will at least contain the kernel of an explanation). This goal will place a variety of situational constraints on the speech act in question while leaving a significant space of possibilities that can be stochastically explored. So in a case of this sort, a creative thought will only be entertained *subsequent to* creative speech-act selection and rehearsal, issuing in a "heard" sentence with the creative content in question. And our hypothesis can be that this is the case whenever creative thoughts are entertained in speech.

What I have provided here is only the very barest and crudest sketch of creative hypothesis generation, of course. It isn't part of my purpose to attempt a detailed account of the processes involved in creative thinking. Rather, my goal is only to motivate cognitive scientists to pay a great deal more attention than they presently do to developing and investigating the explanatory resources of some kind of act-first theory. I believe, however, that I can at least sketch an argument to show that whenever an explanation is offered in thought-first terms, an equally plausible explanation can be constructed by an act-first theorist.

The first premise of this argument is that creative thoughts can only be held in working memory, thereby being available for the "explore" aspect of Geneplore models of creative cognition, if they are first expressed in globally broadcast visual or other imagery or inner speech. According to the model of working memory developed and experimentally investigated over the years by Baddeley and colleagues (e.g., Baddeley & Hitch, 1974; Baddeley & Logie, 1999), the working memory system consists of a central executive that directs and utilizes two "slave" systems, the phonological loop (which issues in inner speech) and the visuo-spatial sketchpad (which results in visual imagery).[17] If this model is correct, then the only way for information to be retained in working memory is for it to be imagistically expressed.

Admittedly, in Baddeley's most recent work (2006) the account has been extended to include an *episodic buffer*, which serves as a gateway to semantic and episodic memory. It might therefore be tempting to think that a subject's creative thoughts could be placed in the episodic buffer directly, in such a way as to make them globally accessible for development and evaluation independent of imagery. But this is not what Baddeley actually has in mind. Rather, the episodic buffer serves to *integrate* the two sensory slave systems with information from semantic and episodic memory, binding them together. There is no suggestion that the episodic buffer can operate alone, presenting our own thoughts to us via global broadcast in the absence of any sensory clothing.[18]

With the claim in place that all creative thoughts need to be imagistically expressed before they can do their work, the second premise is that mental rehearsals of action that would issue in such images can always be selected *directly*, by-passing prior thought altogether, and only issuing in creative thought after the fact, as a result of creative action-selection. For recall from section 3 that the evidence suggests that motor cortices are implicated in all forms of imagery, either driving the movement of visual imagery or underlying the creation of auditory representations in inner speech. So in any case motor-schema activation would need to take place.

Suppose, for example, that the stochastic concept selector proposed by a thought-first theorist works like this: random selections are made from among concepts that have been partially activated by associations made salient in the circumstances, and the resulting thoughts are then formulated into imagery and evaluated. Instead, we can propose that the very same set of associations that partially activates a set of concepts *also* serves to partially activate the corresponding lexical items or visual images, and the stochastic action-selector incorporates some of the latter into a mentally-rehearsed sentence or other image. The result would be the same.

Consider how this might work out in a particular (largely fictional) example. Newton is struck on the head by a falling apple, and it occurs to him that the explanation for falling objects and planetary motions could be the same. A thought-first theorist might say that the falling apple activates the general idea of falling objects, while the roughly-round shape of the apple activates the concept of a moving planet, by association. The stochastic concept-selector then combines both concepts to formulate the thought that planetary motion is the same as objects falling. When expressed in imagery, globally broadcast, and evaluated, this thought is seen to have enough promise to be explored further. An act-first theorist, in contrast, can handle all the same components differently. The initial event and its conceptual associations would partially activate the phrases "falling object" and "moving planet." The stochastic action-selector then incorporates both phrases into the sentence, "falling objects are the same as moving planets," which is then rehearsed and evaluated as previously.

I have argued that whatever explanation a thought-first theorist offers of a particular creative episode, an act-first theorist can co-opt that explanation and utilize its resources, transforming it into an act-first version of the same account. It appears, therefore, that there would have been no need for a distinct thought-first creative mechanism to evolve. Once the act-first system had initially appeared (as the arguments of sections 5 and 7 suggest it would have done), it could have been exapted to cover all of the same ground and serve all of the same functions as its thought-first competitor.

Before concluding this section let me return briefly to the question of creative *products*, like paintings and musical works. We noted in section 1 that these are generally built up piecemeal, via a complex sequence of actions, and that the respects in which they are creative, likewise, can often be factored into the effects of a number of different creative actions or ideas. In such cases there will generally be a complex interplay between thought, action, and perception. For example, an artist might begin with a vague idea of what she wishes to achieve, which she then sketches onto a canvass; looking at it, other creative ideas occur to her and she begins to "flesh out" the painting, changing some aspects and adding others; but as the painting progresses some creative contributions are also made "on-line" in the course of mixing her paints or applying paint to canvass, with the artist subsequently noticing and being pleased with the results; and so on.

How can an *exclusively* act-first account be maintained in the face of such complexity? The answer is implicit in what has already been said above. For the description just provided focuses entirely on what is accessible in the artist's consciousness or is publicly available in the world. (It is such properties that become incorporated into our common-sense view of creativity, therefore, resulting in some or other version of thought-first account.) Yet the initial vague idea, together with each creative thought entertained thereafter, might actually be the product of constrained stochastic action-schema selection and rehearsal, issuing in the conscious imagery that the agent will report as an idea. Hence all of the creative contributions that result in a complex creative object might very well originate in constrained stochastic action-schema activation.

9. Conclusion

I have suggested that an act-first account of human creativity is not only possible but plausible. It is consistent with what we know about the evolution, architecture, and operations of the human mind, and it coheres nicely with a range of empirical data and well-established theoretical models. It deserves to be taken seriously by cognitive scientists interested in addressing the well-springs of human creativity. Moreover, since the account is distinctive in being action-based, it generates a number of unique predictions. The main one is that damage to or interference with motoric areas of cortex should have a negative impact on the generative aspect of creative thinking and problem solving, whereas damage to or interference occurring within temporal or frontal regions of the brain should only adversely affect the evaluative components of creative cognition (either by interfering with global broadcasts or with the cognitive systems that consume such broadcasts). In contrast, the thought-first theory makes no such predictions. These questions remain to be investigated.

In conclusion, I should emphasize the non-demonstrative nature of my arguments. Although I maintain that we have good reasons to think that an act-first account is needed to explain at least some forms of human creativity, the reasons for thinking that creativity is *exclusively* act-first are much more tentative. My main goal has been to get act-first accounts of creativity taken seriously. I hope to have done enough to succeed in that.

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Notes

[1] I assume, here, that objects that are created unintentionally, by mere happenstance or accident, cannot be considered creative—although the act of realizing the usefulness of such an object, or of placing it on public display as worthy of aesthetic consideration, say, might be considered to be so.

[2] Note that a creative outcome that remains within the mind of its creator as a *mere* thought or idea cannot be considered *historically* creative in the fullest sense, since by remaining private it must fail the value and/or usefulness criterion. But it could be *psychologically* so. Think, for example, of someone who creates a novel fantasy that pleases him.

[3] Notice that this gives rise to the possibility of a sort of meta-creativity, in cases where the choice of constraints is itself the outcome of a creative process. Think, for example, of a composer who not only creates some novel melodies but does so within a set of constraints provided by creatively altering the conventions that had previously governed the production of music of that sort.

[4] See Mahon and Caramazza (2008) for an argument that all of the data that has been cited in support of the embodied concepts hypothesis can be accommodated within a modified version of "disembodied" account. And see Negri et al. (2007) for an argument that conceptual and motor competencies dissociate.

[5] Note that it wouldn't be relevant to insist here, as a Humean might do, that movements only count as *actions* when caused by beliefs and desires (i.e., when caused by prior thoughts). The important point for my purposes is that action *schemata* can be activated in the absence of thought. For this then opens up at least the possibility that they might sometimes be activated in this manner *creatively*. Remember, the real target of investigation is the locus (or loci) within the mind of stochastic generativity.

[6] A further illustration of the claim that actions can be initiated without prior thought may be provided by some of the work of Bargh and colleagues (Bargh, 2005; Bargh, Chen, & Burrows, 1996; Bargh, Gollwitzer, Lee-Chair, Barndollar, & Troetschel, 2001). This shows that action schemata (such as walking in the manner of an old man) can be activated and executed by suitable conceptual priming, which presumably doesn't give rise to any *belief* that the subject is an old man, or even to any corresponding thought.

[7] I know of no direct evidence that animals actually utilize all the various components together in such a way as to engage in mental rehearsal. But there are certainly many forms of behavior that it is tempting to interpret in this light. Think, for example, of a cat that is trying to judge whether it can leap from a roof to a nearby ledge: it will *physically* rehearse some of the preparatory actions involved (crouching down as if to jump), while examining the intervening distance intently. Potential examples of rehearsal and creative mental rehearsal in chimpanzees will be discussed in section 6.

[8] The area in question is the superior temporal sulcus together with area FP in the rostral part of the inferior parietal lobule. These are strongly interconnected with each other, and also with area F5 in pre-motor cortex. See Rizzolatti (2005).

[9] From personal communication with Christopher Cherniak (December 6, 2005).

[10] For this reason submarine commanders in the Second World War would throw dice to determine the elements of their zig-zag patrols, thereby making themselves unpredictable to the submarine-hunting vessels on the surface above (Miller, 1997).

[11] While I believe that some insects are genuine thinkers (Carruthers, 2006), this is only in respect of the integration of spatial information with a variety of goals in navigation. I doubt whether the navigational capacities of most moths have this degree of complexity. And although some highly social species are capable of thinking about the behavior of others—and by extension themselves—(Hare, 2007), I very much doubt whether this finding extends to rabbits.

[12] Why do I think that the chimpanzee's planning process utilizes mental rehearsals of action rather than just conceptual thinking? This is because planning surely requires working memory, and there is reason to think that all working memory is image-based, as we shall see in section 8. We have to hand a plausible story about how rehearsals of intended action could give rise to the imagery required for planning, but no such account seems available of how conceptual thought in apes could have the same effect.

[13] Carruthers (2006) speculates that it was the evolution of a disposition to engage in childhood pretend play that may have been crucial in this regard, underlying the development of each of the capacities described here.

[14] Note that two potential pressures for the development of human creativity can be envisaged. One stresses the benefits of mental rehearsals of creatively-generated action schemata for problem solving, as I have done. But an alternative would emphasize sexual selection, suggesting that the earliest expansion of creativity in human life-history might have been in such areas as body-painting, dance, and song (Miller, 2000). Either seem to me possible. But note that each is most naturally construed in an act-first manner.

[15] Here is another challenge: how is it that one can creatively imagine things that one couldn't possibly *do*? If all creativity is action-based, then how is it that the range of creative thoughts far outstrips the range of possible actions? For example, one can imagine the US Capitol building being placed upside-down on its dome and spun like a top. At this point it is important to remember, however, that the parietal visuomotor system is nonconceptual in character. So a rehearsed action of lifting and spinning an object won't represent the object in question as the Capitol building per se, but rather by means of some sort of indexical. Indeed, it seems highly likely that the temporal and parietal systems are coordinated by means of indexicals (Pylyshyn, 2003). Thus a globally broadcast and conceptualized visual presentation of an array of fruit in a bowl might give rise to an intention of the form, "I will eat *that* apple." But by the time this intention reaches the motor system it will have become a nonconceptual instruction to lift a particular object (*that* one) to the mouth, and this instruction will be guided in its execution by nonconceptual percepts within the parietal stream. One would expect, then, that starting from a globally broadcast image of the Capitol building one could generate a motor instruction of the form, "lift, invert, and spin *that*," which when rehearsed will issue in conscious imagery of the object in question being spun on its dome, just as might happen if the object in question were a child's toy. Something similar may be true in all cases where imagination seemingly outstrips action, I submit.

[16] A number of writers on metaphor have pointed out, however, that someone might only realize precisely what thought or feeling he wanted to express *after* having hit upon an apt metaphor (e.g., Moran, 1994). This is, of course, further grist for the act-first mill.

[17] In light of the recent discovery of the important role played by motor imagery in conscious learning and reasoning (Jeannerod, 2006), a third slave system should probably be added. Indeed, see Barnard (1999) for just such a proposal.

[18] Although there are models of working memory that make no commitment to the sensory components of Baddeley's account, such as ACT-R (Anderson, 1993; Lovett, Reder, & Lebiere, 1999) and Soar (Newell, 1990; Young & Lewis, 1999), these derive from an artificial

intelligence tradition that is less closely tied to the explanation of details of human performance.

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