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Part I

Fundamental Concepts

1 Creative Ideas and the Creative Process: Good News and Bad News for the Neuroscience of Creativity

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Every neuroscientist is likely familiar with phrenology, the first science devoted to the proposition that the diverse psychological functions – or mental "faculties" – were located in specific parts of the brain. Who has not seen a phrenology chart with the borders between the various faculties precisely delineated on the cranium? To be sure, phrenology is now considered a notorious example of a pseudo-science. Yet that contemporary judgement often ignores the fact that phrenology was founded by a genuine scientist, Franz Joseph Gall. Although Gall's ideas about the localization of function were based on some erroneous assumptions – most notably a close congruence between cerebral cortex and cranium – phrenology probably deserves more respect than other pseudo-sciences of those times, such as Franz Mesmer's mesmerism. True or not, a creativity researcher like me might find it remarkable that the extensive list of faculties – dozens of them – does not include creativity! Nor anything similar, whether imagination, inventiveness, or originality. The closest faculty to creativity is perhaps wit (or "mirthfulness"), but surely that concept remains remote. Hence, are modern neuroscientists willing to rush in where phrenologists might have feared to tread?

In this chapter, I want to discuss why neuroscientists should tread carefully when studying creativity. Unlike such phrenological faculties as sight, hearing, taste, and smell, the psychology of creativity is necessarily riddled with complexities that must be deeply considered if the neuroscience of creativity is to become a cumulative and coherent science (cf. Arden, Chavez, Grazioplene, & Jung, 2010; Dietrich & Kanso, 2010; Gonen-Yaacovi et al., 2013; Sawyer, 2011). These complexities can be assigned to two big questions. First, what is a creative idea? Second, by what process are creative ideas produced?

Creative Ideas – What and Who?

Presumably, the creative *process* generates creative ideas, the creative *person* engages in the creative process producing those ideas, and the creative *product* contains the creative ideas that the creative person acquires through that creative process. But observe that these statements all suppose that we know what the adjective "creative" actually means. Without a definition, these seemingly obvious assertions actually become meaningless. It turns out that defining creativity is no simple task (Simonton, 2016). In fact, the definition requires that we address two independent questions. We should begin by asking: *What* criteria must be used in judging an idea's creativity? Once that issue is resolved, we then must inquire: *Who* evaluates those criteria in assessing the idea's creativity?

What Are the Creativity Criteria?

For a very long time, many creativity researchers subscribed to what has been called the "standard definition," namely, "Creativity requires both originality and effectiveness" (Runco & Jaeger, 2012, p. 92). Thus, two criteria are imposed, albeit different researchers might substitute approximate synonyms for either criterion: (a) novelty or uniqueness for originality; and

(b) usefulness, utility, value, appropriateness, or meaningfulness for effectiveness (Simonton, 2016). However, others have argued that a third criterion *must* be added. For instance, Boden (2004) stipulated that creative ideas must be novel, valuable, and surprising, a three-criterion definition that closely corresponds to that used by the United States Patent Office, namely, new, useful, and nonobvious (Simonton, 2012b).

Recently, the three-part definition has been formally expressed by the following equation (Simonton, 2013a, 2016, 2017): $c = (1 - p)u(1 - v)$. Here, c is creativity, p is the idea's initial probability, so that $(1 - p)$ gives its originality, u is the finally assessed utility or usefulness, and v is the prior knowledge of the idea's utility, which makes $(1 - v)$ a gauge of its surprise (i.e., how much new knowledge is gained). The values for c, p, u, and v, as well as $(1 - p)$ and $(1 - v)$, all range between 0 and 1, like probabilities or proportions. Hence, minimum = 0, maximum = 1, and middling ≈ 0.5. Moreover, because c is the multiplicative function of the three factors, $c = 0$ if any of its components equals 0. In words, a creative idea must be original *and* useful *and* surprising. Each separate criterion is thus rendered necessary but not sufficient. For example, an utterly useless idea cannot be creative no matter how original and surprising – such as constructing a bank vault out of cellophane.

This three-criteria definition is vastly superior to the standard definition (Simonton, 2016). Indeed, the latter definition makes no sense whatsoever. After all, the two-criteria definition can be expressed as $c = (1 - p)u$, indicating that the most creative ideas have a low probability but a high utility. This then leads to a paradox: How can a highly useful idea have such a low probability? The only rational answer to that enigma is that the creator does not already know the utility, necessitating that the prior knowledge value v approach zero. For any reasonable creature, if a highly useful idea was already known to be useful, then its probability would have to be high rather than low. This logical and psychological necessity then mandates that $(1 - v)$ be added as the third factor. The standard definition is plainly untenable.

Three critical consequences follow necessarily from the three-criteria definition. These consequences concern incubation periods, domain-specific expertise, and uncreative ideas.

Incubation periods. Wallas (1926) offered a stage theory of creative problem-solving that remains frequently cited nearly a century later: Preparation, Incubation, Illumination, and Verification. The creator starts by preparing an understanding of the problem, encountering difficulties that then lead to the incubation period in which the individual is not consciously thinking about the problem. With sufficient incubation the creator may have an insight, eureka, or "ah-ha" experience in which a solution flashes to mind (Hélie & Sun, 2010). Yet because such inspirations are by no means guaranteed to work, this illumination phase must be followed by the verification phase in which the idea is directly tested, whether externally or internally (cf. Dennett, 1995). If this test fails to confirm the idea's utility, then the cycle will continue in the hope that an effective solution is finally found.

Yet is the incubation period actually required? Might not the creative individual skip directly from preparation to illumination? That is, as soon as the problem is properly understood, the solution might come to mind without any need to work on irrelevant tasks in the meantime (cf. Boden 2004). The three criteria provide a precise answer to this question: Both yes and no! The precision of the answer comes from recognizing that the correct response depends on the magnitude of creativity. If we can assume that utility is high and prior knowledge low, then creativity obviously maximizes as the initial probability goes to zero (i.e., if $u \rightarrow 1$ and $v \rightarrow 0$, then $c \rightarrow 1$ as $p \rightarrow 0$). Hence, the most creative ideas under these conditions would have an initial probability of zero ($p = 0$). So the importance of incubation follows from the definition.

At the same time, even when the initial probability exceeds zero ($p > 0$), the creativity can still exceed zero ($c > 0$). To illustrate, suppose that after the requisite preparation the creator has an immediate but moderate hunch that a certain low-probability idea will solve the problem. The parameter values might be $p = 0.2$, $u = 1$, and $v = 0.5$ (for the "hunch"), which yields $c = 0.4$. A lot of ordinary creativity probably operates at this middling level, reasonably creative ideas emerging without any incubation whatsoever.

Yet given this direct implication of the definition, we might ask whether the *length* of the incubation period has any relevance for an idea's creativity. The definition makes no provision for this duration having any impact. This omission follows from the plausible assumption that the time elapsed before the response strength exceeds zero is most likely the function of random stimuli (cf. Seifert, Meyer, Davidson, Patalano, & Yaniv, 1995) and capricious trains of thought (cf. Mandler, 1995). The first recorded "Eureka!" moment in history occurred when Archimedes took a bath, yet the time that he waited before he felt he was (over)due for some personal hygiene should not determine the evaluation of the idea's creativity.

The good news: Researchers who study the neuroscience of creative insights are not wasting their time (e.g., Bowden, Jung-Beeman, Fleck, & Kounios, 2005). The incubation–illumination phase shift is not required for all creative ideas to emerge, but the cognitive shift is positively associated with the emergence of the most highly creative ideas.

Domain-specific expertise. Some researchers are inclined to believe that creativity is domain specific (Kaufman, Baer, & Glăveanu, 2017). Albert Einstein could no more paint *Guernica* than Pablo Picasso could work out the equations for the general theory of relativity. Yet such a belief conflates content with process. An analogy with language is useful here (Simonton, 2017). No doubt that someone who learns English cannot automatically speak Mandarin. Yet the kinds of psychological processes necessary to learn and apply either language must overlap considerably. Both languages require that the user recognize phonemes and morphemes, wrap the vocal apparatus around specific consonants, vowels, and tones, learn lexicons and master syntax, establish correspondences between the spoken and written word, and acquire the appropriate pragmatics of when to say this and when to say that to whom. If otherwise, then there would have to exist at least as many linguistics departments as there are world languages. We would also have to wonder why almost any *Homo sapiens* can master any human tongue on this planet, yet no non-human whatsoever can acquire even basic proficiency in any natural language. The human language "module" is generic, not specific.

Recall that the three-criteria definition parallels the standards used by the United States Patent Office to evaluate patent applications (www.uspto.gov/inventors/patents.jsp). In particular, the surprise criterion corresponds to the nonobvious criterion, the two just stressing different aspects of the prior knowledge value v. When $u = v = 1$, a useful idea is obvious, but when $u = 1$ but $v = 0$, the same idea is surprising. Significantly, when the Patent Office applies this criterion in evaluating applications, they refer not to the opinion of the average person on the street but rather to the judgment of somebody with "ordinary skill in the art" (www.uspto.gov/web/offices/pac/mpep/documents/2100_2141_03.htm). In other words, the idea cannot be derived directly from domain-specific expertise. A necessary even if not sufficient condition for $c \to 1$ is for $v \to 0$. This necessity does not mean that relevant expertise is absolutely irrelevant. On the contrary, such expertise is most often essential to constructing the utility criterion (Simonton, 2015). What does it actually signify to invent a better mousetrap or discover a cure for cancer? If a person has no knowledge of past solutions to the problem of invasive rodents or is completely ignorant of how various cancers appear and grow, then coming up with a highly effective device or medical intervention becomes impossible. It is just that knowing exactly what you're looking for does not ensure that you'll actually find what you're looking for.

Hence, more good news: Because creativity cannot just involve the direct application of domain-specific expertise, neuroscientists can concentrate their methods on whatever happens in the brain that produces surprising or nonobvious ideas. Creativity must be primarily domain-generic, not domain-specific (Simonton, 2017).

Uncreative ideas. According to the three-criteria definition, creativity can be optimized just a single way: Simultaneously maximize originality, utility, and surprise. If the idea is commonplace, useless, or obvious, or any combination of possible zero values, then an uncreative idea results. Each exerts veto power over the rest. In effect, this definition implies that ideas may be uncreative in multiple ways, seven to be exact (Simonton, 2016). Although not all possibilities are equally interesting or valuable, it is instructive to examine them all. So all eight potential outcomes are shown in Table 1.1.

The creative outcome is immediately followed by one representing routine, reproductive, or habitual thinking or behavior (e.g., $p = u = v = 1$). The idea is highly useful, that utility is known in advance, so that the initial probability is supremely high. Indeed, any rational creature would operate so that $p \to 1$ as $uv \to 1$ (aka "learning"). Closely related is the next outcome, rational suppression, in which the initial probability approaches zero because the idea is already known in advance to be useless (i.e., as $u \to 0$ and $v \to 1$, then $p \to 0$). These latter parameter values may have been "learned the hard way" through the extinction of maladaptive responses.

The next two outcomes both involve high-probability ideas but low prior knowledge values, with only the utilities differing. In the case of the fortuitous responses, the idea with the highest probability also has the highest utility, but the person is ignorant of the actual utility because the idea was just a "lucky guess" – such as winning the lottery using your mother's birthdate. In contrast, "problem-finding" occurs when a high probability idea is revealed to be useless, the individual having no prior knowledge of that inutility. This outcome can be considered a form of problem-finding because an idea that was expected to work based on past experience fails to work. The person is then

Table 1.1 *Creative and noncreative outcomes according to the three-criteria definition.*

Initial probability	Final utility	Prior knowledge	Outcome
$p \to 0$	$u \to 1$	$v \to 0$	Creative ideas or responses ($c \to 1$)
$p \to 1$	$u \to 1$	$v \to 1$	Routine, reproductive, or habitual ideas or responses
$p \to 0$	$u \to 0$	$v \to 1$	Rational suppression (e.g., extinguished responses)
$p \to 1$	$u \to 1$	$v \to 0$	Fortuitous responses (e.g., "lucky guesses")
$p \to 1$	$u \to 0$	$v \to 0$	Problem-finding (surprising expectation violations)
$p \to 0$	$u \to 1$	$v \to 1$	Irrational suppression
$p \to 1$	$u \to 0$	$v \to 1$	Irrational perseveration
$p \to 0$	$u \to 0$	$v \to 0$	Mind wandering or behavioral exploration

Note: The symbol "→" should be read "approaches." Table modified from Simonton (2016).

obliged to look for a different solution to the problem. An example would occur when a scientist makes a theoretical prediction that is contradicted by the data.

The next two outcomes should only be found in irrational thinking. On the one hand, "irrational suppression" entails having an idea with a very low probability despite having a strong prior expectation that the idea would be useful. On the other hand, "irrational perseveration" involves having an idea with a high probability even though the person already has prior knowledge that the idea will not work. If sufficiently frequent and pervasive, these two outcomes might be taken together as a definition of mental illness (Simonton, 2016).

The eighth outcome is perhaps the most curious: This has been called "blissful ignorance" (Simonton, 2016), but it might be better labeled either "mind wandering" or "behavioral exploration," depending on whether the response involves a thought or an action. In either case, the idea has a very low probability, but it does not really matter because the idea is likely useless, a fact unknown to the person anyway. The vague thoughts that drift by in dreams, daydreams, and drug trips fall into this category. Naturally, if the reverie just so happens to come up with a highly useful idea, the outcome is highly creative instead (Smallwood & Schooler, 2015). Similarly, a composer just absentmindedly tinkering at the keyboard may chance upon an original, surprising, and useful melody – as illustrated by the episode by which Edward Elgar discovered the theme for his popular *Enigma Variations*.

Why present all of these possibilities? Because they offer some bad news for any neuroscience of creativity. There is no such thing as a bipolar dimension with creative ideas at one end and uncreative ideas at the other end. Instead, creativity is multidimensional. Worse yet, the mental mechanisms for the diverse outcomes must be quite distinct. Rational suppression is just as uncreative as irrational perseveration, but the former indicates sanity, the latter insanity. Neuroscientists need to keep themselves ever aware of these niceties: Surely different areas of the brain will "light up" under the eight alternative scenarios! Indeed, under the eighth scenario, the brain may not show any localized activity, but rather might fall back on the "default mode network" recently associated with creativity (e.g., Kühn et al., 2014). Such a mental state allows the generation of ideas with the parameters $p \to 0$ and $v \to 0$, a tiny subset of which may have the parameter value $u \to 1$ (which can still be produced precisely because of the low prior knowledge value). This rare outcome then leads to a flash of insight that disrupts the random reverie and reverts the mind to concentrated attention once again.

Who Evaluates Those Creativity Criteria?

I received my PhD in social psychology, having written a doctoral dissertation specifically titled "The social psychology of creativity" (Simonton, 1974; cf. Amabile, 1983). That background has perhaps made me more sensitive to a critical distinction that is too often overlooked in creativity research, including in the neurosciences. The distinction is that between personal and consensual creativity, or what is sometimes called "little-c" and "Big-C" creativity (Simonton, 2013b; cf. Kaufman & Beghetto, 2009). The three-criteria definition discussed in the previous section quite literally concerned "little-c" or personal creativity. Not just c but also p, u, and v were all in lower case. That means that individual creators are basing the creativity assessment of an idea's initial probability, final utility, and prior knowledge value based on their own subjective experiences during a given episode, such as solving a particular problem. It matters not one iota if others would have a different opinion about these three criteria.

In stark contrast, consensual creativity does require the assessments of others besides the idea's creator, such as coworkers, supervisors, colleagues, referees, patent examiners, investors, critics, festival juries, curators, impresarios, consumers, audiences, connoisseurs, patrons, fans, scholars, and historians (the exact mix depending on the specific domain of achievement and the scope of the evaluation). To incorporate these judgments, we must revise the earlier definition by putting the parameters in uppercase: $C = (1 - P)U(1 - V)$, where P, U, and V represent some aggregate sum of numerous independent assessments using the three criteria (Simonton, 2013b). We now obtain (also literally) Big-C creativity.

Nonetheless, a problem emerges at once: Whose assessments should be averaged to produce a composite measure? By definition, a consensual evaluation should represent a consensus, yet seldom is that the case. For instance, research on cinematic creativity tends to use the evaluations of three different groups: moviegoers who buy tickets, film critics who write reviews, and industry professionals who bestow awards on their colleagues (Simonton, 2011b). Given that these three groups do not always agree with each other (e.g., blockbusters seldom earn critical acclaim), their separate opinions cannot just be averaged together. The resulting composite would suffer from prohibitively low reliability. So which of the three represents consensual creativity? Any choice must be arbitrary. It gets worse: Consensual evaluations can change radically over time. For example, the judgments of moviegoers, critics, and professionals may not correspond with much later identifications of "film classics" by, say, the American Film Institute (Ginsburgh, 2003). An infamous example is the 1941 *Citizen Kane*, now widely considered by film historians to be the greatest film to emerge out of Hollywood's Golden Age.

Needless to say, a temporal shift in consensual evaluations is especially conspicuous in "neglected" or "rediscovered" geniuses, such as Gregor Mendel or Emily Dickenson. Obviously, if consensual creativity lacks any consensus or stability, it cannot be taken as representative of any corresponding psychological process. Mendel thought he had made an important scientific discovery, and Dickenson had faith that she was writing great poetry. No doubt they both were engaged in creativity during their respective lifetimes. Yet neither was considered highly creative until long after their deaths, when actual creativity must cease. The instability works in the other direction, too. The historical record is riddled with people who were once considered highly creative but who now are lucky to earn a footnote in an exhaustive history (Weisberg, 2015). Even earning a Nobel Prize is no guarantee. Today it boggles the mind that Nils Gustaf Dalén could get the 1912 Nobel Prize for Physics for his having designed automatic valves for use with the gas accumulators in buoys and lighthouses. Strikingly, Dalén received this high honor when Albert Einstein was already well overdue for the same Nobel after having revolutionized theoretical physics. Einstein did not receive that recognition until 1921, when the committee only explicitly honored his 1905 work on the photoelectric effect – ignoring his far more creative relativity theories!

Note that the problem raised by the personal–consensual creativity contrast permeates the actual "creativity" measures used in research, neuroscientific or otherwise. On the one hand, some instruments emphasize personal creativity, as evinced in those self-report measures that simply ask respondents to identify what they consider to be their creative accomplishments (e.g., Richards, Kinney, Lunde, Benet, & Merzel, 1988; cf. Silvia, Wigert, Reiter-Palmon, & Kaufman, 2012). On the other hand, some instruments stress consensual creativity, as seen in the Consensual Assessment Technique (Amabile, 1982). Yet complicating matters still more is that some instruments mix personal and consensual judgments, yielding hybrid measures with ambiguous implications. For instance, the Creative Achievement Questionnaire begins each creativity scale at the personal level but then switches to the consensual level, so that low but nonzero scores reflect little-c and high scores Big-C (Carson, Peterson, & Higgins, 2005; cf. Simonton, 2012a, 2013b). Even a putatively creative process measure like the Alternative Uses Test is somewhat of a mixed bag (Guilford, 1967). Scoring for originality, fluency, flexibility, and elaboration entails some consensual judgments, particularly given the prerequisite that the generated uses must be judged useful to count. However, those utility assessments might easily miss a genuine utility that is personally justified because the individual actually knows more than the judges about the potential functions of the given objects, whether brick or paper clip.

By now the bad news should be manifest: Neuroscientists must be cautious about the inferences they draw from any creativity tests they decide to use. Those measures that emphasize personal creativity will come closest to the creative process going on in a creator's head, whereas those that emphasize consensual creativity are contaminated with sundry social, cultural, economic, political, and historical factors that may have nothing to do with either psychology or neuroscience (see also Simonton, 2010). Caveat emptor!

Creative Process – or Processes and/or Procedures?

Earlier I offered the good news that creativity is not domain-specific. A creative idea cannot originate via the straightforward application of well-established disciplinary procedures. As seen in Table 1.1, such ideas must be considered routine, reproductive, or habitual rather than truly creative. So what neuroscientists must scrutinize is the creative process that applies to all domains of creativity. Now comes the bad news: There's no such thing as *the* creative process! At the very least we must speak in the plural, multiple processes rather than a single process. To appreciate this multiplicity, consider that creativity researchers have themselves identified the following processes: cognitive disinhibition (or defocused attention), intuition, remote association, imagination, divergent thinking (including originality, fluency, flexibility, and elaboration), overinclusive (allusive) thinking, and primary (or primordial) process (or "regression in the service of the ego"), such as occur in dreams, daydreams, and certain altered states of consciousness (Carson, 2014; Simonton, 2017; Simonton & Damian, 2013). Even if a few of these processes may overlap to some degree, that's still quite a sizable inventory! Many more than one, for sure.

The bad news gets yet worse: Creativity does not have to involve processes at all, but rather can entail specific procedures. By "procedure" I mean some conscious and deliberate tactic for producing creative ideas. Examples include analogy, conceptual reframing (frame shifting), finding the right question, broadening perspective, reversal, juggling induction and deduction, abduction, dissecting the problem, tinkering, and play as well as a toolkit of heuristic search methods, such as means-end analysis, hill-climbing, working backwards, and trial-and-error (Finke, Ward, & Smith, 1992; Ness, 2013; Newell & Simon, 1972; Simonton & Damian, 2013). To be sure, not only may some of these procedures overlap, but some processes can become procedures if applied deliberately rather than intuitively, such as divergent thinking and remote association. Indeed, Janusian, Homospatial, and Sep-Con Articulation thinking might go either way, process or procedure, according to the context (Rothenberg, 2015). Alternatively, some have demonstrated that creativity can involve just the application of ordinary thought, the thinking presumably indistinguishable by any brain imaging technique (Weisberg, 2014). As if the news could not get any more dismal, it must be acknowledged that many of these processes and procedures can operate across distinct modalities. For instance, divergent thinking can involve visual, verbal, kinesthetic, and gustatory/

olfactory imagery – as revealed in painting, poetry, choreography, and the culinary arts.

Does all this mental variety mean that creativity does not entail any generic process or procedure? No, not at all. These processes and procedures all represent alternative means to generate low probability ideas with comparably low prior knowledge values (Simonton, 2017). Because $p \rightarrow 0$, an incubation period will often be required, and because $v \rightarrow 0$, the idea is not guaranteed to be useful. The latter consequence is why Wallas (1926) added a verification stage after the illumination stage. Not all inspirations, no matter how exciting, actually pan out. Accordingly, the individual must engage in some "generation and test," "trial and error," or "blind variation and selective retention" or BVSR (Campbell, 1960; Nickles, 2003; Simonton, 2011a). Only when $u \rightarrow 1$ and $v \rightarrow 1$ is testing or selection not required. Yet in that case, as seen in Table 1.1, the only possible outcomes are either routine thinking (where $p \rightarrow 1$) or irrational suppression (where $p \rightarrow 0$). A highly creative idea is simply not an option under those parameters.

In truth, BVSR can operate at two levels (Simonton, 2011a). At one level, a creator might generate and test multiple analogies in the quest for that particular analogy that seems to work best. But at the other level, the creator may engage in trial and error to determine which procedure works best. For example, after despairing of using analogical reasoning to solve a problem, the person may try out alternative heuristics to see which one finds the solution, the application of each of those heuristics then entailing BVSR once more. Too often creativity researchers will overlook this critical necessity. Yet to the extent that an idea is truly creative, it should become impossible to pick the optimal process or procedure in advance (see the "No Free Lunch" theorem discussed in Nickles, 2003). Sometimes analogy will work, other times divergent thinking, and yet other times frame-shifting or some other approach. And if none of those work, perhaps the sole recourse is to "sleep on it" or to take a bath. Thus, the only genuine requirements for creativity are cognitive flexibility and motivational persistence. Highly creative people will attack a problem from many different angles, enduring many false starts and dead ends, before they finally complete their quest – if they manage to do so at all!

Apropos of the last unfortunate contingency, Einstein wasted the final three decades of his career on developing a unified field theory that absolutely *never* worked. As he himself admitted, "Most of my intellectual offspring end up very young in the graveyard of disappointed hopes" (www.aps.org/publications/apsnews/200512/history.cfm). He was still going over his notes on the subject the day before he died. Can the rest of us expect to do any better?

So are the foregoing points good or bad news for a neuroscience of creativity? The answer probably depends on the neuroscientist's aspirations. On the one hand, if the researcher wishes to identify *the* cerebral locus of creative ideas, that quest is necessarily quixotic. Presumably, cognitive mechanisms that produced Einstein's general theory of relativity were identical to those that generated his unified field theory, yet the former product was creative whereas the latter was not. On the other hand, if the goal is limited to the processes and procedures by which creators generate prospects for eventual test, whether or not the ideas survive those tests, then the neuroscience of creativity can operate on firmer ground (see, e.g., Jung et al., 2015). Nothing in the brain produces creativity like a gland secretes a hormone.

Conclusion

If the neuroscience of creativity is to make progress as a bona-fide scientific endeavor, then it must cope with the complexities of the phenomenon – a phenomenon far more complex than the norm for standard neuroscientific methods. This complexity was first seen in the discussion of what counts as a creative idea. The complexity was witnessed again in the treatment of the creative processes and procedures that produce those ideas. Given these real complications, sometimes the implications were good news, other times bad news. Nevertheless, when the positives and negatives are taken altogether, I believe that researchers should be optimistic about the field's future. Yet that optimism assumes that neuroscientists will deal adequately with the phenomenon's intricacies. Otherwise, the net result may be little more than a neophrenology that just rashly circles a section of the cortex and arbitrarily labels it "creativity."

References

Amabile, T. M. (1982). Social psychology of creativity: A consensual assessment technique. *Journal of Personality and Social Psychology*, 43, 997–1013.

Amabile, T. M. (1983). *The social psychology of creativity*. New York, NY: Springer-Verlag.

Arden, R., Chavez, R. S., Grazioplene, R., & Jung, R. E. (2010). Neuroimaging creativity: A psychometric view. *Behavioural Brain Research*, 214(2), 143–156.

Boden, M. A. (2004). *The creative mind: Myths & mechanisms* (2nd ed.). New York, NY: Routledge.

Bowden, E. M., Jung-Beeman, M., Fleck, J., & Kounios, J. (2005). New approaches to demystifying insight. *Trends in Cognitive Sciences*, 9, 322–328.

Campbell, D. T. (1960). Blind variation and selective retention in creative thought as in other knowledge processes. *Psychological Review*, 67, 380–400.

Carson, S. H. (2014). Cognitive disinhibition, creativity, and psychopathology. In D. K. Simonton (Ed.), *The Wiley handbook of genius* (pp. 198–221). Oxford, UK: Wiley.

Carson, S., Peterson, J. B., & Higgins, D. M. (2005). Reliability, validity, and factor structure of the Creative Achievement Questionnaire. *Creativity Research Journal*, 17, 37–50.

Dennett, D. C. (1995). *Darwin's dangerous idea: Evolution and the meanings of life*. New York, NY: Simon & Schuster.

Dietrich, A., & Kanso, R. (2010). A review of EEG, ERP, and neuroimaging studies of creativity and insight. *Psychological Bulletin*, 136, 822–848.

Finke, R. A., Ward, T. B., & Smith, S. M. (1992). *Creative cognition: Theory, research, applications*. Cambridge, MA: MIT Press.

Ginsburgh, V. (2003). Awards, success and aesthetic quality in the arts. *Journal of Economic Perspectives*, 17, 99–111.

Gonen-Yaacovi, G., de Souza, L. C., Levy, R., Urbanski, M., Josse, G., & Volle, E. (2013). Rostral and caudal prefrontal contribution to creativity: A meta-analysis of functional imaging data. *Frontiers in Human Neuroscience*, 7 (Article 465). doi:10.3389/fnhum.2013.00465

Guilford, J. P. (1967). *The nature of human intelligence*. New York, NY: McGraw-Hill.

Hélie, S., & Sun, R. (2010). Incubation, insight, and creative problem solving: A unified theory and a connectionist model. *Psychological Review*, 117, 994–1024.

Jung, R. E., Wertz, C. J., Meadows, C. A., Ryman, S. G., Vakhtin, A. A., & Flores, R. A. (2015). Quantity yields quality when it comes to creativity: A brain and behavioral test of the equal-odds rule. *Frontiers in Psychology*, 6(864). doi: 10.3389/fpsyg.2015.00864

Kaufman, J. C., & Beghetto, R. A. (2009). Beyond big and little: The four c model of creativity. *Review of General Psychology*, 13, 1–13.

Kaufman, J. C., Baer, J., & Glăveanu, V. P. (Eds.). (2017). *Cambridge handbook of creativity across different domains.* New York, NY: Cambridge University Press.

Kühn, S., Ritter, S. M., Müller, B. C. N., van Baaren, R. B., Brass, M., & Dijksterhuis, A. (2014). The importance of the default mode network in creativity – A structural MRI study. *Journal of Creative Behavior*, 48, 152–163.

Mandler, G. (1995). Origins and consequences of novelty. In S. M. Smith, T. B. Ward, & R. A. Finke (Eds.), *The creative cognition approach* (pp. 9–25). Cambridge, MA: MIT Press.