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Creativity and Discovery as Blind Variation: Campbell's (1960) BVSR Model After the Half-Century Mark

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This article assesses and extends Campbell's (1960) classic theory that creativity and discovery depend on blind variation and selective retention (BVSR), with special attention given to *blind* variations (BVs). The treatment begins by defining creativity and discovery, variant blindness versus sightedness, variant utility and selection, and ideational variants versus creative products. These definitions lead to BV identification criteria: (a) intended BV, which entails both systematic and stochastic combinatorial procedures; and (b) implied BV, which involves both variations with properties of blindness (variation superfluity and backtracking) and processes that should yield variant blindness (associative richness, defocused attention, behavioral tinkering, and heuristic search). These conceptual definitions and identification criteria then have implications for four persistent issues, namely, domain expertise, ideational randomness, analogical equivalence, and personal volition. Once BV is suitably conceptualized, Campbell's theory continues to provide a fruitful approach to the understanding of both creativity and discovery.

Keywords: creativity, discovery, blind variation, selective retention, Donald Campbell

Donald T. Campbell was a former president of the American Psychological Association (APA) and a recipient of APA's Distinguished Scientific Contribution Award. Although he received his PhD in social psychology and did his earliest research on attitudes, he expanded his interests to encompass other areas of psychology as well as sociology, anthropology, education, and philosophy. Today he is perhaps best known for his methodological contributions, such as quasi-experimental designs and the multitrait-multimethod matrix (Campbell, 1988). Nonetheless, Campbell also published a classic 1960 article on creativity (Cziko, 1998; Simonton, 1998). Here he argued that creative thought depends on the twofold procedure of blind variation (BV) and selective retention (SR), or BVSR. The generative component of BVSR is the BV. With less than complete clarity, Campbell specified that BVs had two attributes. First, "the variations emitted [must] be independent of the environmental conditions of the occasion of their occurrence" (p. 381). Second, "the occurrence of trials individually [must] be uncorrelated with the solution, in that specific correct trials are no more likely to occur at any one point in a series of trials than another, nor than specific incorrect trials" (p. 381). Later these two attributes will be bestowed more precise and transparent definitions. Right now, the main point is that Campbell claimed that BVSR was responsible not just for creativity, but also for discovery.

Although BVSR was intended to provide a theoretical basis for understanding creativity and discovery, Campbell never developed the BVSR model into a full-fledged psychological theory of those phenomena. Instead, he turned his attention to applying a modified version of his basic position to sociocultural evolution and evolutionary epistemology (e.g., Campbell, 1965, 1974a). Perhaps because of this disciplinary shift, Campbell's ideas seemed initially to have had the biggest impact on philosophical research (e.g., Bradie, 2001; Briskman, 1980/2009; Nickles, 2003; Stein & Lipton, 1989; Wuketits, 2001). This philosophical impact was probably facilitated by the strong congruence between Campbell's views and those of the philosopher Karl Popper (1963, 1972; see Kronfeldner, 2010, for discussion). Because the scientific utility of Campbell's psychological model of creativity is largely independent of the philosophical validity of his evolutionary epistemology, these later intellectual developments may have diverted attention away from his model's important implications regarding the creative process.

However, about three decades after its 1960 publication, the BVSR model of creativity and discovery began to undergo psychological development (e.g., Martindale, 1990, 1995; Staw, 1990). The most prolific contributor to this development was Simonton, who has published numerous journal articles (e.g., 1999b, 2005, 2007a, 2005, 2007a), book chapters (e.g., 1995, 2003a, 2009a, 2003a, 2009a), and books (1988b, 1999c, 1999c) arguing for some version of Campbell's theory of creativity and discovery. At the same time, Simonton's efforts have encountered considerable criticism from those who do not accept the basic premise that creativity can be explicated in BVSR terms. Many of these critiques were published as commentaries on three target articles: (a) a presentation of the general theory (Simonton, 1999b), (b) an application of the theory specifically to Pablo Picasso's sketches for his 1937 *Guernica* (Simonton, 2007a), and (c) an elaboration of the theory in terms of formal combinatorial models (Simonton, 2010a). In addition, several researchers have published independent criticisms that challenged BVSR's application to creativity for various reasons and to varying degrees.

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Among researchers in psychology, the partial or total critics include Gabora (2005, 2007); Perkins (1994); Sternberg (1998), and Weisberg (2000), while critics outside the discipline include Thagard (1988) and Kronfeldner (2010), both philosophers, and Dasgupta (2004), a computer scientist.

Although Simonton has attempted to respond to the various criticisms (e.g., Simonton, 1999a, 2005, 2007b, 2010a), his exposition of Campbell's (1960) position has not always been a positive contribution. Sometimes Simonton elaborated BVSR in directions that undercut the argument on behalf of Campbell's own model of creativity. For example, Simonton's (e.g., 1999c, 2005, 2005) explicit identification of BVSR with "Darwinism" was tactically unwise insofar as it suggested a close analogy that many consider utterly tenable (Gabora, 2005, 2007; Kronfeldner, 2010). Simonton's nomenclature also led to needless confusions over Darwinism as directly derived from Darwin and the subsequent Neo-Darwinism (or the New Synthesis) that emerged in the early 20th century as a conceptual and mathematical integration of evolutionary theory with Mendelian genetics (Simonton, 2007b, 2010c). The attempt to distinguish between primary and secondary Darwinism proved of no avail (e.g., Simonton, 1999c, 2003a).

In sum, Campbell's (1960) article continues to provoke discussion and controversy even a half century after its publication. Nevertheless, rather than spinning wheels and staying in the same spot, the dispute has made some progress: The diverse statements both pro and con must structure the central issues in the debate (e.g., Heyes & Hull, 2001; Kronfeldner, 2010; Nickles, 2003). It has become obvious that the most continual objection to a BVSR model of creativity concerns the BV component. Many researchers have emphasized that creativity and discovery are sighted, guided, or directed rather than blind (e.g., Kronfeldner, 2010; Sternberg, 1998; Thagard, 1988). Accordingly, ideational variations should signify structured applications of domain-specific expertise (Weisberg, 2006; but see Weisberg & Hass, 2007). Selection becomes largely irrelevant because the selection supposedly occurs upfront, in the initial generative process. Once ideas are supremely preselected, selection per se is reduced to pedestrian "double checking" or "quality control." The less prominent is the BV, the less crucial is the SR.

Thus, the focus of this article is on whether creativity and discovery really require blind ideational variations. The first task is to define the key terms necessary for discussion. What do we mean by creativity and discovery? What do we take to represent "blind" variations? Which variants are selected and how are they selected? Because defining scientific concepts is always an excursion into somewhat inaccessible abstraction, I must ask readers to bear with me in this specific section. I promise that the abstract definitions will bear sweet fruit.

Indeed, the definitions will be immediately used to derive identification criteria for deciding whether creativity and discovery can really depend on the BV part of BVSR. These criteria are then directly applied to a diversity of concrete examples, such as the creativity or discovery entailed in Picasso's *Guernica*, Beethoven's Fifth Symphony, Kepler's Third Law, and Watson's DNA base codes. In addition, BV can be connected with several processes and procedures linked to creativity and discovery, namely, associative richness, defocused attention, behavioral tinkering, and heuristic search. Along the way, I will have occasion to quote such notables as Michael Faraday, Charles Darwin, Alexander Bain, Hermann von Helmholtz, William Stanley Jevons, William James, Albert Einstein, James D. Watson, and Neal E. Miller—all of whom provided testimonials to the operation of BV as defined in this article.

Once the identification criteria have been amply illustrated, we can concentrate on the implications regarding four important theoretical issues. First, is BV inconsistent with a creator's almost inevitable possession of domain-specific expertise? Second, does BV demand that ideas be randomly generated? Third, does the concept of BV rely on a tight analogy with Darwin's theory of evolution? Fourth, is BV incompatible with the conspicuous place that personal volition must have in the creative process? Contrary to what many of BVSR critics believe, the answer to all four of these questions will be the same—a resounding "No!"

Conceptual Definitions

Below I deal with four definitional matters: (a) creativity and discovery, (b) variant blindness versus sightedness, (c) variant utility and selection, and (d) ideational variants versus creative products. These definitions will enable us to avoid confusions about what is and is not involved in BVSR theory.

Creativity and Discovery

Many researchers in the area of creativity adopt a two-criterion definition, namely that creativity requires novelty and utility (Runco, 2004; Simonton, 2000b). An idea is novel if it is sufficiently original to be distinguishable from what has already become an established part of a given domain of knowledge, expression, or practice. An idea is useful if it solves some problem or otherwise meets some need or satisfies some specified criterion, whether scientific or aesthetic (e.g., truth or beauty). The second criterion ensures that the novelty or originality is not maladaptive, even insane. One special advantage of the two-criterion definition is that it can be applied to any phenomenon that generates original adaptations, including organic evolution, antibody formation, neurological development, and operant conditioning (cf. Cziko, 1995, 2001). Furthermore, this definition has an immediate connection with any variation-selection model of creativity, BVSR or otherwise. Variations provide the novelties while selection determines the subset of those novelties that also feature utility.

Even so, the two-criterion definition of creativity has two problems: One, it is not rigorous enough; and, two, it does not capture the complexity of the phenomenon. Thus, I will adopt the three-criterion definition that the U.S. Patent Office uses when evaluating applications (http://www.uspto.gov/inventors/patents.jsp). Besides novel and useful, an invention cannot receive protection under the law unless it has no *obvious* connection with previous inventions. That is, a patentable invention must be new, useful, and nonobvious. In deciding whether an application satisfies the third criterion, the judgment is based on domain-specific expertise rather than the general knowledge of the average person. A more psychological way of specifying this third touchstone is that the idea must provoke surprise (see also Boden, 2004). Even an expert in the field will be surprised at the idea, not seeing any facile connection with what came before. One implicit feature of this three-criterion definition is that it makes it more evident why the ideational variations should not be completely sighted. BVs are intrinsically more likely to be surprising than are sighted variations. Another inherent asset is that this definition makes it easier to encompass discovery as an aspect of creativity. Discoveries are surprising by their very nature.[1]

To be sure, creativity and discovery are often considered to represent separate phenomena (Weisberg, 2006). The former seems to be something that a creator *invents*, whereas the latter is something that a discoverer *reveals*. In the former case, something would not exist without the creator having invented it, whereas in the latter case, something would exist but remain unknown without the discoverer having revealed it. Moreover, very often this distinction is associated with the difference between art and science. Artists are truly creative, whereas scientists merely make discoveries. Michelangelo may have created the Sistine Chapel frescoes, but Newton discovered the universal law of gravitation. Stated differently, if Michelangelo had never been born, there would be something else painted on the chapel's ceiling, but if Newton had never been born, someone else would have come across the universal law of gravitation (Price, 1963). Although there may be some grain of truth to this contrast, the difference may be a matter more of degree than kind. In a sense, the arts require more creativity than do the sciences, a possibility intimated by some philosophers (e.g., Kant, 1790/1952). Consequently, scientists may depend on BVSR processes much less than artists do (Simonton, 2009a). Where scientists are constrained by what *could be*, artists are free to explore what *might be* (as in science fiction) or even what they would *like to be* (as in idealized art or utopian literature).

Nonetheless, it remains justified to discuss both creativity and discovery as if they represent two aspects of the same broad phenomenon. Scientists have to be creative to make discoveries, and artists make discoveries in route to creativity. Einstein's special relativity theory required creativity just as Picasso's *Guernica* was dependent on discovery—as illustrated by the artist's sketches. Upon observing the Picasso's manner of working, the art historian Ernst Gombrich (1969) affirmed that Picasso took "as a matter of course that creation itself is exploration. He does not plan, he watches the weirdest beings rise under his hands and assume a life of their own" (p. 356). Hence, it should come as no surprise that most proponents and opponents of BVSR usually treat discovery and creativity together (e.g., Kantorovich, 1993; Kronfeldner, 2010). I will do the same here.

Variant Blindness Versus Sightedness

As should have been apparent from this article's first paragraph, Campbell (1960) did not provide a precise definition of what it means for a variation to be blind. Rather, he merely offered a qualitative and somewhat intuitive conception. Campbell was deliberately vague about the nature of the BVs because he wisely recognized that the variations are generated by more than one mechanism. As a result, he needed a definition that would apply to all possible forms of BVs. For instance, Campbell identified the methodical sweep of radar as blind, as well as the output of any random combinatorial process—two radically different means. Campbell was also quick to point out that blindness did not require the equiprobability of variants. One variant could be far more probable than another is so long as the difference in the probabilities did not reflect their probable success (but for his inconsistencies on this position, see Kronfeldner, 2010).

Regrettably, Campbell (1960) never really clarified his conception in subsequent publications (e.g., Campbell, 1965, 1974a). If anything, he somewhat muddied the water by changing his terminology (e.g., substituting "unjustified" for "blind" in Campbell, 1974b). Yet in the absence of a more precise definition, it is impossible to make progress for understanding the extent to which creativity and discovery require BV, or whether they do so at all. Kronfeldner (2010) maintained that the most appropriate definition is the one used in evolutionary biology. After all, the BVSR model of creativity is often believed to be inextricably dependent on an analogy with biological evolution. Kronfeldner's specifically cited the definition that Sober (1992) provided regarding whether a given genetic mutation is directed or undirected. Later, Simonton (2010a) elaborated Sober's definition to obtain a more explicit definition of sightedness as well as blindness. In the present article, Simonton's elaboration will be developed further to (a) render the definition generalizable to a diversity of BV mechanisms (not just those combinatorial), (b) provide detailed criteria for separating sightedness from blindness, and (c) make explicit the continuum connecting sighted and blind processes. I follow both Sober (1992) and Simonton (2010a) in considering only two possible variants. Yet the basic formalism can be extended to instances of three or more possible variants (Simonton, in press), albeit the multiple-variant definition would then become far too mathematical for our present purposes.

I start with two extreme cases—beginning with sighted variations before turning to blind variants—after which I will turn to the continuum connecting the two.

First extreme case: Unambiguously sighted variations. Let X and Y represent the two possible variants, with their respective subjective probabilities of $p(X)$ and $p(Y)$. Because the two variants are possible, I can assume that both $p(X) > 0$ and $p(Y) > 0$. Associated with each of these two variants is a utility u (cf. the "fitness" w used by Sober, 1992). These utilities will be notated here as $u(X)$ and $u(Y)$, respectively. Because I seek definitions with maximal applicability, utility is here defined as the probability of final selection and retention—the other half of the hypothesized BVSR process. Put differently, $u(X)$ is the probability that X proves maximally useful, adaptive, or functional according to the appropriate criteria, whether scientific or artistic, as decided by the creative individual engaged in the process (Simonton, 2010a). Hence, in theory, values of u, like values of p, fall in the interval 0 to 1. Without loss in generality, let us assume that $p(X) > p(Y)$. Then the two variants are *sighted* if $u(X) > u(Y) \rightarrow p(X) > p(Y)$, where the symbol "$\rightarrow$" means "implies" (Sober, 1992). In words, one variant is more probable than the other variant exactly *because* the creator knows that it is more useful than the other variant. Because the ideation was frontloaded by the expected utilities, the

[1] Although it is easy to confound novelty with surprise in the abstract, the criteria become more distinct in concrete examples. Both the Lorentz-Fitzgerald contraction hypothesis and Einstein's theory of relativity provide an explanation for the null result of the Michelson-Morley interferomenter experiment, but the former does so post hoc within the context of classical physics whereas the latter does so a priori by overturning basic assumptions of that scientific paradigm. Even if both solutions are novel and useful—indeed, they yield identical equations—Einstein's solution is the far more surprising, rendering relativity revolutionary.

variation-generational process must then be sighted (cf. Kronfeldner, 2010).

It is essential to acknowledge that the definition is confined to *possible* variants. One of the most common misunderstandings of Campbell's (1960) theory is that it presumes that ideational possibilities cannot be preselected according to the stipulations of a given "problem space." It should also be noted that if either (a) $p(X) = u(X) = 0$ and $p(Y) = u(Y) = 1$ or (b) $p(Y) = u(Y) = 0$ and $p(X) = u(X) = 1$, then ideational variation per se ceases to exist, and BVSR does not then apply in a strict sense. Yet under this scenario, the singular "variant" would most likely be considered neither novel nor surprising and hence uncreative. On the contrary, the only novel and surprising outcome in this case would occur when the variant with $p = 1$ turned out unexpectedly to have $u = 0$ (e.g., a disconfirmed prediction from a well-established theory). Better yet, the only outcome that would be not just novel and surprising but also useful would be the serendipitous discovery of a variant with the initial value of $p = 0$ even though $u = 1$. An instance would be Alexander Fleming's discovery of the antibiotic properties of penicillin, a breakthrough that could not possibly have been anticipated even given his substantial expertise in the area of antiseptics.

Second extreme case: Unambiguously BVs. In contrast to the foregoing, the following two conditions describe variant pairs that are incontestably blind:

1. The two possible variants have equal probabilities even though their utilities are very unequal; that is, $p(X) = p(Y)$ although $u(X) \neq u(Y)$. This circumstance applies to fork-in-the-road dilemmas where one road is decidedly better (shorter, straighter, more flat, safer, etc.) and the other road is unquestionably worse (longer, more tortuous, steeper, more dangerous, etc.), but the poor traveler has no idea which is which—and so must choose by flipping a coin. Blind ideational variants are very often precisely of this character. They occur whenever at least two ideas are deemed virtually equiprobable despite the fact that their actual prospects of being true are extremely unequal. One is objectively "right" and the other is objectively "wrong" the subjective equivalence of their likelihoods be what it may.

2. The relative magnitudes of the two variant probabilities and their utilities are reversed; for example, $p(X) > p(Y)$ although $u(X) < u(Y)$. An illustration may be found in Maier's (1931) classic two string problem. Suppose two strings are hanging from the laboratory ceiling and the research participant must tie the ends together even though it is impossible to reach one end while holding the other with arms fully outstretched. Nonetheless, say that the participant is given the opportunity to use any of a number of objects, including a pair of pliers. The response variant with the highest probability is to use the pliers to extend the arm's reach even though the pliers are still not long enough to do the trick. In contrast, the response with the far lower probability is to use the pliers as a pendulum weight, tying the tool to the end of one string, setting it in motion, and catching it while holding the other string. It is comparatively unlikely that most participants in the experiment had ever used pliers in that manner (see also Maier, 1940). It represents an "unusual use" in the parlance of one very common creativity test (Guilford, 1967). That is, p(pendulum/pliers) ≈ 0 even though u(pendulum/pliers) $= 1$ (see also Simonton, in press).

Although the above two conditions provide unequivocal evidence of blindness, they do not exhaust all conceivable manifestations of BVs. In fact, it is feasible for the two variants to be blind even when their probabilities correspond perfectly with their utilities, with the proviso that the latter do not imply the former. Variant probabilities are then still ignorant of variant utility, any correspondence being coincidental. This may be considered a formal definition of the "lucky guess." Sometimes blindness requires an inference from additional information. Even if the ps are exactly proportional to the us, BV may obtain if the creator is ignorant of that fact. Sightedness means that the us must imply the ps, not just have a accidental connection.

Intermediate cases: The sighted-blind continuum. The distinction between sighted and BVs is equivalent to the distinction that Toulmin (1972) advanced between variations that are *coupled* to selection and those that are *decoupled* from selection. If "the factors responsible for the selective perpetuation of variants are entirely unrelated to those responsible for the original generation of those same variants" (p. 337), then variation and selection are decoupled, and hence the variants blindly emitted. One advantage of Toulmin's terminology is that it avoids some of the unfortunate but irrelevant associations that some BVSR critics have to the term "blind" (e.g., Doyle, 2008; Sternberg, 1998).

Even so, it becomes more useful to elaborate an idea that was not developed in Campbell (1960): The opposition between blind and sighted variations is not qualitative but rather quantitative. BVSR can depend on differing proportions of blindness and sightedness (cf. Kronfeldner, 2010). This variance originates two ways.

1. The degree of preselection imposed on the ideational variants. The definition provided earlier assumes that the variants are confined to the permissible or conceivable rather than the impermissible, inconceivable, or impossible. In the sciences, either a priori (logical) or a posteriori (factual) reasoning may specify that $p(Z) = 0$ because $u(Z) = 0$. The extent to which ideational variants undergo preselection depends on the nature of the problem. Certainly preselection is less prevalent in artistic creativity than in scientific creativity (Simonton, 2009a). Although "artistic license" is often permitted in a sci-fi story, a scientific theory must be more restricted by logic and fact. Yet even in the arts some limits will be imposed, whether stylistic or thematic (Martindale, 1990). In any case, because preselection is frequently fallible (i.e., partially blind), it may omit false negatives and admit false positives (see also Simonton, in press). The former are variants of the type $p(Z) = 0$ but $u(Z) > 0$, the latter of the type $p(Z) > 0$ but $u(Z) = 0$. Both preselection errors increase blindness in the overall variation process.

2. The magnitude of decoupling remaining in the preselected ideational variants. Even among the variants that survive preselection, the magnitude of decoupling can differ. In some instances, the variant probabilities may be partly implied by the variant utilities even if the utilities do not determine those variant probabilities. The coupling constitutes merely a slight bias in the correct direction. To illustrate, if $u(X) = 0$ and $u(Y) = 1$ leads to the weak expectation or "hunch" that $p(X) < p(Y)$ but not that $p(X) = 0$ and $p(Y) = 1$, then the variants exhibit some degree of coupling. The preselected variants can be called more sighted according to the size of the inequality relating the two probabilities. The bigger the differential, the larger is the sightedness.

In the abstract, these two bases of quantitative sightedness-blindness are uncorrelated. Preselection might generate merely two entirely decoupled variants, or preselection might produce a dozen variants with some modest magnitude of coupling. Nevertheless, it would seem most probable that the two sources are positively correlated. The more variants surviving preselection, the higher is the likelihood that their relative probabilities are decoupled from their respective utilities. We could then array the set of variants along a continuous scale.[2]

Variant Utility and Selection

Utility has been defined as the probability of selection and retention during a BVSR episode. Because this probability, like that for a variant's generation, is subjective rather than objective, it remains possible that what the individual finds useful will not be judged as such by other members of the domain (Csikszentmihályi, 1999; Simonton, 2010a). In this vein, Boden (2004) distinguished between P-creativity (psychological) and H-creativity (historical), only the latter requiring social certification. A similar distinction is that between little-c (everyday) creativity and Big-C (influential) creativity (Simonton, 2010b; see Kaufman & Beghetto, 2009, for finer distinctions). All that said, we can assume that the creator, discoverer, or inventor first has to judge whether an idea passes the test before it is handed on for the judgment of colleagues, critics, patrons, publishers, or producers. If the individual fails to conclude that an idea is novel, useful, and surprising, then it is unlikely that others will get an opportunity to render a contrary opinion. Personal creativity is a prerequisite for socially certified creativity.

That in mind, even at the individual (psychological) level, the selection process may adopt distinct forms. In particular, I must introduce two contrasts: simultaneous versus sequential selection and external versus internal selection.

Simultaneous versus sequential selection. The relative utility of variants X and Y are assessed simultaneously when both variants are given the option to putatively "live or die" at the same time, whereas utility is assessed sequentially when first X is tested and then Y even though the order of testing was not determined a priori by relative utility. Although creativity often entails sequential selection, this generalization also has many exceptions. For instance, two or more alternative variants can accumulate before one is selected. An example would be where X and Y represent two equally plausible explanations for a given phenomenon so that $p(X) = p(Y)$ although $u(X) \neq u(Y)$. In this situation, the scientist may opt to conduct a critical test that will determine which is correct, pitting the predictions of theory X directly against those of theory Y. This would count as simultaneous selection. Yet the investigator might have instead decided to first test X and then test Y, which would constitute sequential selection.

In creativity, simultaneous and sequential selection can even occur with the same set of ideational variants. Picasso's sketches for *Guernica* provide an illustration. Often Picasso would put a particular sketch aside and start exploring alternatives of a very different kind. Still, the earlier sketch would not have "become extinct" because the artist would often decide later to go back to that earlier sketch and use its identifiable imagery in the final painting (cf. Weisberg, 2004). Indeed, not one single major figure in *Guernica* was based on the very last sketch of that particular figure (Simonton, 2007a). Hence, Picasso was largely engaged in generating graphic variants for each figure in the painting and then later selecting those that fit the overall picture. In a way, the variants were produced sequentially but selected more or less simultaneously. As Simonton (2007b) put it, we can easily "imagine Picasso holding up two distinct sketches for a particular figure, deliberating the pros and cons of each, and then saying to himself 'That one!'" (p. 390).

External versus internal selection. Orthogonal to the previous contrast, selection may be external or internal. In the former, the variant is assessed directly against the environment, as occurs in an experimental test. External selection is inherently more objective as a consequence. In the latter, internal selection, the variant is tested against a mental representation of the environment, such as a cognitive map or mental model. Internal selection has been termed "Popperian" in recognition of Popper's statement that such internalization "permits our hypotheses to die in our stead" (Dennett, 1995, p. 375). Because of the greater subjectivity, internal selection places a premium on acquiring highly accurate and detailed internal representations of the external world. This necessity would often demand that the creator acquire a sufficient mastery of the relevant artistic or scientific domain. It is interesting to note that sometimes a creative individual has to resort to external selection because internal selection fails. Later we will come across implicit examples when I discuss behavioral tinkering.

Ideational Variants Versus Creative Products

Campbell (1960) was explicit that the variants in his BVSR model were singular "thought trials"—an expression he uses well more than a dozen times throughout his article. Hence, the unit of selection was the individual idea evoked in a given problem-solving situation, not the final product that emerged from this process, whether poem, painting, composition, or journal article. Indeed, a key rationale for engaging in BV is to help ensure that the end product has higher odds of proving successful. As a case in point, Picasso produced so many diverse sketches for his *Guernica* with the specific purpose of improving the final painting (Arnheim, 1962; Doyle, 2008). The BVs depicted in these sketches rendered the resultant painting sighted rather blind (Simonton, 2007a). After all, the images that remained in *Guernica* were those that had also been subjected to SR, the second part of the BVSR procedure.

Unhappily, other advocates of BVSR to creativity and discovery have not been so careful in this usage. Most problematic was Simonton's tendency, dating from his earliest publications (e.g., Simonton, 1988b), to treat the finished creative product as the unit of selection rather than the individual creative ideas entering that product. This more molar conception led Simonton to propose the

[2] Using linear algebra, Simonton (in press) has formally defined a continuous measure that can be applied to any set of k variants. The resulting measure ranges from 0 for perfect blindness to 1 for perfect sightedness, and corresponds to a sixfold typology of variants. That mathematical formalism is not necessary for discussing the examples treated in this article.

"constant-probability-of-success model" (Simonton, 1988a) or the "equal-odds rule" (Simonton, 1997) with respect to the relation between quantity and quality of productive output both across and within careers. More specifically, Simonton inferred that (a) those creators who produce the most products in a career are expected to produce the most high-impact products and (b) those periods within the career of any given creator in which they produce the most products should be those in which the creator produces the most high-impact products. Simonton's predictions were based on the false assumption that because products represent variations and because variations are blind, then the quality (or creativity) of products would vary as a probabilistic function of quantity (or productivity). Produce more and the odds increase that the creator produces something good. Although the equal-odds rule still seems to apply to the sciences (Simonton, 1991, 2004), albeit for more complex reasons, its application to the arts has become more questionable, at least in the area of musical creativity (Hass & Weisberg, 2009; Kozbelt, 2008). This inconsistency reinforces Campbell's original position that ideational variants are fed into the selectionist hopper, not entire products. Products normally consist of many separate components, only a subset of which may actually have been subject to BVSR processes. Although variants can be 100% blind, products almost never are (see also Ericsson, 1999; Kozbelt, 2008).

This is not to say that creative products cannot become units of selection at another level. Once an individual publishes or disseminates a given creation or discovery, the product becomes subject to sociocultural (or interpersonal) rather than cognitive (or intrapersonal) selection (Kim, 2001; Simonton, 2004, 2010a). Some products will "survive and reproduce" in the sociocultural system, and others will pass into oblivion. The products may even become fragmented into little pieces, one single crumb becoming a so-called "meme" (Dawkins, 1989) that proliferates independently from the whole work, such as the ubiquitous "duh-duh-duh-dah" opening motif of Beethoven's Fifth Symphony (Blackmore, 1999). Some would suggest that these postcreativity developments still count as episodes of "blind" variation insofar as the initial product or meme becomes selected according to criteria decoupled from the creator's understanding or intentions (e.g., Kantorovich, 1993; Kim, 2001). Others would take an antagonistic position, arguing that such contributions remain extremely sighted insofar as they have already been selected at the individual level (e.g., Boyd & Richerson, 1985). Fortunately, as Kronfeldner (2010) has pointed out, this particular debate does not have to be resolved if our specific concern is whether the intrapersonal process of creativity functions according to Campbell's (1960) BVSR (see also Martindale, 1999).[3]

Identification Criteria

The critical question now becomes how to determine whether creativity and discovery depend on blind ideational variations. Such identification can be carried out two ways: intention and implication.

Intended BV

This criterion is the easiest to apply, because sometimes the ideational variants are *intended* to be blind by design. That is, a BV mechanism may be deliberately imposed. These mechanisms may be of two kinds: systematic and stochastic.

Systematic BV. A straightforward example of systematic BV is that cited by Campbell (1960): radar sweeps. The radar on top of an airport control tower will scan the horizon 360° or 2π radians. At any time t the radar will be sending and receiving long-wave radiation at angle θ_t, so it is obvious that $p(\theta_t)$ is identical for all angles (i.e., all possible polar coordinates to the horizon are equiprobable). Even so, the utilities $u(\theta_t)$ will not be identical for all t. On the contrary, perhaps an echo indicating a "discovered" object is only returned within a very narrow arc. The variants are patently decoupled from their utility, and hence intentionally blind. The same principle applies for other a priori scans, such as search grids. Astronomers can conduct searches of the heavens that are blind by design, pointing their optical or radio telescopes toward arbitrary spots in the sky without any way of knowing whether they will come across something interesting. Archeologists, paleontologists, and physical anthropologists can impose comparable search grids on their digs with similar purposeful blindness, a blindness that ensures that no potential discovery is ever overlooked within the preselected confines of the search.

A second example comes from the computer programs that purport to make scientific discoveries (e.g., Langley, Simon, Bradshaw, & Zythow, 1987; Shrager & Langley, 1990). Even though the details differ from program to program, all can be said to operate according to the principle of a heuristic search through a problem space. Yet close examination reveals that this methodical search by no means completely sighted even if not utterly blind. To see how this is so, consider BACON, a program devised to make discoveries using Baconian induction (e.g., Bradshaw, Langley, & Simon, 1983). A frequently reported example is BACON'S discovery of Kepler's Third Law of planetary motion. This law relates the planet's period of rotation around the sun, P, to its distance from the sun, D (actually the semimajor axis of the ellipse describing the orbit). The law says that $P^2 = kD^3$, that is, the square of the period is proportional to the cube of the distance. When given the raw data for the planets, BACON was able to arrive at the same law. By means of sequential selection, the program used three preset heuristics to generate and test the following solutions: $P/D = k$, $P/D^2 = k$, and, lastly, $P^2/D^3 = k$ (the product of the previous two quotients), the latter giving the correct answer.[4] These three successive solutions can be assigned utilities $u(P/D) = 0$, $u(P/D^2) = 0$, and $u(P^2/D^3) = 1$. Given that the generate-and-test order can be presumed to indicate a set of

[3] The BVSR theory can be incorporated into more comprehensive models that include the social selection process that determines whether what is novel, useful, and surprising to the individual is also judged so by the field or society at large (e.g., Simonton, 2010a; see also James, 1880; Kim, 2001). Yet these complications are not needed for understanding the psychological aspects of creativity and discovery (Boden, 2004).

[4] One can question whether BACON's three heuristics did not take advantage of over three centuries of hindsight. To the extent that these heuristics were not available when Kepler first tackled the problem, then his original solution may have required more blindness and less sightedness. This difference would partially explain why Kepler took far longer to solve the problem than did BACON. Sometimes scientists have to create or discover heuristics before they can solve a problem. These heuristics are the products of past BVSR episodes (Campbell, 1960).

sequentially adjusting solution probabilities, the three-step cycle still exhibits a definite amount of decoupling. For sure, the decoupling is not absolute insofar as the heuristics allowed BACON to "sightfully" sidestep two solutions of the same form, namely, $P^2/D = k$ and $P^2/D^2 = k$. Still, Simon (1983) was only partly justified in holding that this simulated discovery "certainly does not rely on a brute-force trial-and-error exploration of the data" (p. 4571), because solely the "brute-force" ascription in incorrect. The heuristics reduced the number of "trials and errors" by only half.

Stochastic BV. Radar scans, search grids, and discovery programs can all be viewed as generating *systematic* blind variants. Moreover, radar scans, search grids, and discovery programs can also be classed as *combinatorial* as well as systematic. The first explores all possible polar coordinates in an encircled region, the second examines all possible Cartesian coordinates in a bounded space, and the third scrutinizes possible mathematical functions of a given type (i.e., quotients of two variables with variant powers). Far more interesting are combinatorial variants that are *stochastic* rather than systematic. These are especially noteworthy because all participants in the debate about BVSR creativity concur that random combinations are necessarily blind (e.g., Kronfeldner, 2010). If variants are generated by "chance permutations" (cf. Simonton, 1988b), then their likelihoods of generation (the *p*s) cannot possibly be ascribed to the variant utilities (the *u*s). Accordingly, computer programs that prove to be creative via random combinatorial procedures provide evidence for the importance of BV.

Happily, we do not have to look very far for such evidence: Computer scientists have already written a large number of problem-solving programs that operate on BVSR principles, using random combinatorial procedures. These programs adopt many names, including evolutionary algorithms, genetic algorithms, evolutionary programming, and genetic programming (Goldberg, 1989; Holland, 1975, 1992; Koza, 1992). Notwithstanding the explicitly random combinatorial operations underlying the procedures, these programs are accomplished problem solvers. They can make forecasts in currency trading, design stream and gas turbines, plan fiber-optic telecommunication networks, enhance the efficiency of jet engines, and improve mining operations and oil exploration (Holland, 1992), and solve difficult problems in algebraic equations, the determination of animal foraging behavior, the design of electrical circuits, and the identification of optimal game-playing strategies (Koza, 1994; Koza, Bennett, Andre, & Keane, 1999). These BVSR programs can even replicate scientific results like the aforementioned discovery programs have been able to do. For instance, Kepler's Third Law was rediscovered using genetic programming (Koza, 1992). Therefore, blind stochastic combinatorial models can yield the same creative solutions as blind systematic combinatorial models.

Probably only a minority of computer programs that evince creativity or discovery are explicitly BVSR in construction. Nevertheless, it may be impossible to construct a computer program that simulates these phenomena without introducing some blind component, and often this component will be stochastic rather than systematic. After examining the inner workings of highly creative programs, Boden (2004) concluded, "what is useful for creativity in minds and evolution is useful for creative computers too. A convincing computer model of creativity would need some capacity for making random associations and/or transformations," a requirement that would often be met "by reference to lists of random numbers" (p. 226). Apparently, creativity and discovery can only be successfully simulated by introducing some BV mechanism, a stipulation that most often leads to stochastic combinatorial procedures (Simonton, 2003b, 2004, 2010a).

Even so, it is apparent that systematic and stochastic BV mechanisms are in key respects equivalent. Both systematic BACON and stochastic genetic programming were able to arrive at Kepler's Third Law. Although the former relied on a heuristic generate-and-test search while the latter depended on an explicitly BVSR procedure, they both converged on the same discovery. The only procedural overlap between the two operations was the realization of blindness. Blindness may be either systematic or stochastic, but it remains blindness in either case, any differences in BV being matters of degree rather than kind. A little thought reveals that the same operational equivalence holds for other instances of intended BV. As an example, rather than conduct a systematic radar scan, functionally equivalent outcomes could be obtained by randomly selecting all angles (without replacement until all directions have been exhausted). Evidently, it is most vital for a variant to be blind. It does not matter whether the specific process that generated the blindness is systematic or stochastic.

Implied BV

The previous section raises a very intriguing puzzle. If the only way computers can simulate creativity or discovery is to incorporate BV—whether systematic or stochastic—does that fact in and of itself imply that human creators must indeed operate by parallel means? Does it really make sense that computers need blindness to accomplish what humans do using sightedness? Alternatively, is it the case that human creativity and discovery are also dependent on an intrusion of variation blindness? If the latter holds, is it reasonable to infer BV from the actual facts of human creativity and discovery?

Admittedly, to infer BV a posteriori is more difficult and tenuous than to note merely when BV has been implemented a priori. Even so, a plausible case can be made for BVSR even by this post hoc approach. The argument is twofold. First, ideational variations may themselves betray telltale signs of partial or complete blindness. Second, the underlying ideational processes cannot be expected to yield fully sighted variants.

Variations with properties of blindness. The ideational variants emitted during the process of creativity have certain characteristic signs that they were generated by a BV process. Two related attributes are especially telling: superfluity and backtracking.

1. Variation superfluity. The variants must be blind to the extent that they are too numerous and too diverse than would be expected from a sighted process; this inference is strengthened whenever two or more variants are incommensurate or contradictory (e.g., $X \rightarrow$ not-Y and $Y \rightarrow$ not-X). The physicist Michael Faraday once admitted, "the world little knows how many of the thoughts and theories which have passed through the mind of a scientific investigator have been crushed in silence and secrecy by his own severe criticism and adverse examinations; that in the most successful instances not a tenth of the suggestions, the hopes, the wishes, the preliminary conclusions have been realized" (quoted in Beveridge, 1957, p. 79; for evidence, see Tweney, 1989). Darwin (1892/1958) similarly wrote "I have steadily endeavored to keep my mind free so as to give up any hypothesis, however much believed (and I cannot resist forming one on every subject) as soon as facts are shown to be opposed to it. Indeed, I have had no choice but to act in this manner, for with the exception of the Coral Reefs, I cannot remember a single first-formed hypothesis which had not after a time to be given up or greatly modified" (pp. 55–56). This superfluity is seldom apparent in the final publications because the variants have been conscientiously filtered through the SR part of the process. Even worse, as the psychologist Neal Miller once confessed,

> Published reports of research are written with the wisdom of hindsight. They leave out the initial groping and fumbling to save journal space (and perhaps also to save face) and exclude almost all of those attempts that are abandoned as failures. Therefore, they present a misleading picture which is far too orderly and simple of the actual process of trying to extend the frontiers of science into unknown territory. (Cohen, 1977, p. 243)

Although the superfluity is absent in the final product, the phenomenon is often noticeable in the scientist's laboratory notebooks or in the artist's preliminary sketches.

This variant superfluity can certainly be seen in Picasso's *Guernica* sketches (Simonton, 2007a; see also Weisberg, 2004). There are 45 altogether, but because some of these treat two or more figures, the virtual total is 79; 11 concern the bull, 9 the mother with her dead child, 11 the fallen warrior, 23 the horse, 6 the woman with the lamp, and 11 the weeping woman. What is remarkable about these sketches is not just their number but also their diversity. Some of the sketches do not seem to have anything to do with the final painting, but rather appear strictly incommensurate with the others in the same series (e.g., Sketch 19 "Head of Man with Bull's Horns" and Sketch 22 "Bull with Human Head"; see Arnheim, 1962). Such experiments just pop in and drop out without any immediate antecedents and without any apparent consequences—except as dead ends that tentatively narrow the range of alternatives. Even after Picasso began work directly on the large canvas, he would make some rather dramatic additions and subtractions. For example, he would occasionally attach wallpaper designs (and even human hair) to the painting to experiment with the possibility of making it into a collage, in striking contrast to the final highly linear and almost monochromatic end result.

Although superfluous variants provide strong evidence of an underlying BV process, we have to take care not to assume that the converse is true, namely that a BV process will necessarily produce superfluity (Simonton, 2005). This is a common inferential mistake made by both proponents and opponents of BVSR (e.g., Dasgupta, 2004; Simonton, 1999c). BVSR only requires that there be a minimum of two variants satisfying the decoupling conditions in any given problem-solving condition. The inferential importance of superfluity is that the greater the number and diversity of variants, the lower the odds that (a) they all have equal utilities and (b) those utilities underlie the generation probabilities. Furthermore, the power of this inference becomes reinforced by the second clue.

2. Variation backtracking. Creativity, like operant conditioning, tends to operate according to sequential rather than simultaneous selection. If the consecutive thought trials were sighted, then we would expect them to approach the final form asymptotically. Each generation-and-test would provide the necessary feedback to inch closer to the desired goal. By comparison, if the variants were inherently blind, then sometimes they would get "warmer" and sometimes "colder"—without any consistent pattern. Expressed differently, if variant utility was plotted as a function of variant order in the series of thought trials, then the utilities would be positive monotonic for the sighted case and nonmonotonic for the blind case (Simonton, 2007a, in press). Each time a variant gets "colder" it would represent a downward turn in the plot, introducing a mandatory zig-zag. The latter is precisely what holds for the *Guernica* sketches (Simonton, 2007a). The sketches are decidedly nonmonotonic with a distinctive advance-retreat pattern (see also Damian & Simonton, in press; Doyle, 2008; Weisberg, 2004). Very frequently, the sketch closest to the final image in the painting appeared very early on in the series for that figure. This was especially the case for the mother with dead child and the weeping woman: In both instances, the second sketch was the one most proximal to the finished version. The subsequent sketches proved to constitute "blind alleys" in which the artist did not know in advance that he was taking the wrong track.

The orchestral conductor Leonard Bernstein (1959) provided a fascinating example of backtracking when Beethoven composed the conclusion to the first movement of his epochal Fifth Symphony. The composer's sketches indicate that he thought that the initial version of the coda was unsatisfactory because it was too short. So he remedied that presumed defect by making the coda longer. However, the composer eventually realized "that the trouble with his first ending was not that it was too short, but rather that it was not short enough" (p. 104). Beethoven therefore backtracked to aim toward the opposite direction from which he was originally headed. The ensuing expressive conciseness and concentration might be called a brilliant stroke of genius except that Beethoven "had to struggle and agonize before he realized so apparently simple a thing" (p. 104). The paradoxical solution was not obvious even to this great composer.

Helmholtz (1898) published an introspective report about his own thought trials that indicates that backtracking occurs in the sciences as well as in the arts:

> I only succeeded in solving such problems after many devious ways, by the gradually increasing generalisation of favorable examples, and by a series of fortunate guesses. I had to compare myself with an Alpine climber, who, not knowing the way, ascends slowly and with toil, and is often compelled to retrace his steps because his progress is stopped; sometimes by reasoning, and sometimes by accident, he hits upon traces of a fresh path, which again leads him a little further; and finally, when he has reached the goal, he finds to his annoyance a royal road on which he might have ridden up if he had been clever enough to find the right starting-point at the outset. (p. 282)[5]

The higher the proportion of backtracks, and the greater their magnitude, the stronger is the corresponding inference that the variants must have relied on blindness rather than sightedness. Indeed, it is reasonable to make an even stronger induction: The more frequent and more conspicuous the backtracking the higher

[5] The last sentence in this quote deserves emphasis: Helmholtz eventually discovers the "royal road" that leads directly to the goal. Some problems, such as the Tower of Hanoi, also require backtracking, but there is no royal road. Even after someone figures out the solution, he or she has to backtrack every time (Hayes, 1989). Backtracking is inherent to the problem, not an extraneous feature stemming from the problem solver's ignorance.

the likelihood that even the more successful variants lacked sightedness. Every "you're getting colder" implies that every "you're getting warmer" might have been nothing more than fortuitous. In the classic scenario of the drunkard engaged in a random walk, there will of necessity be occasions where the sad chap walks in the correct direction (e.g., toward home and a warm bed). Yet the drunkard should not be credited with sightedness if the next step goes off in the opposite direction. To engage in such asymmetrical attributions of blindness versus sightedness is to fall victim to the hindsight bias (Fischhoff, 2007).

By the way, it is worth reporting that not all of the thought trials leading up to a creative product need be completely blind. The series of *Guernica* sketches that Picasso did for the woman holding the lamp display hardly any backtracking (Simonton, 2007a). This image was adapted from the figure of a girl holding a lamp in his earlier *Minotauromachy* and in a modified form appeared in the very first sketch for the painting (see also Weisberg, 2004). The transformations it underwent to the final version are for all practical purposes positive monotonic—largely just filling in the details and adjusting its relationship with the other figures in the painting. The sketch history for this figure shows what Picasso could have done had he not depended on BV to obtain the result he desired. He could have started with a general compositional sketch showing all of the figures, and then successively refined each of them in conjunction with the others until he arrived at a satisfactory result (Simonton, 2007a). If BVSR theory is correct, the outcome would not then have been a masterpiece. The product would have been too obvious, too similar to what he had done before.

Processes that should yield blindness. There is no such thing as a single creative process. Instead, there are a great many different processes, mechanisms, or procedures that all can generate creative ideas or discoveries in various circumstances (Simonton & Damian, in press; see also Dietrich & Kanso, 2010). Any given problem will almost invariably be solved via a small subset of these operations, the specific composition of that subset varying from problem to problem in a seemingly erratic manner. However, among the most common processes involve associative richness, defocused attention, behavioral tinkering, and heuristic search.

1. Associative richness. James (1880) described the psychological processes that provided the basis of individual originality. These processes were chaotic rather than systematic, combinatorial or analogical rather than logical. In particular, he wrote that

> instead of thoughts of concrete things patiently following one another in a beaten track of habitual suggestion, we have the most abrupt cross-cuts and transitions from one idea to another, the most rarefied abstractions and discriminations, the most unheard of combination of elements, the subtlest associations of analogy; in a word, we seem suddenly introduced into a seething cauldron of ideas, where everything is fizzling and bobbling about in a state of bewildering activity, where partnerships can be joined or loosened in an instant, treadmill routine is unknown, and the unexpected seems only law. (p. 456)

Although contemporary researchers would not dare to describe creative thought in such an effusive, even rhapsodic manner, it is has become patent that creativity often requires the ability to engage in somewhat unconstrained associations. This associative richness may be obtained by means of remote associations (Mednick, 1962), rare associations (Gough, 1976), divergent thinking of various kinds (Carson, Peterson, & Higgins, 2005; e.g., "unusual uses"; Guilford, 1967), primordial or primary process cognition (Kris, 1952; Martindale, 1990; Suler, 1980), Janusian associations (i.e., thinking in opposites; Rothenberg, 1990), allusive or overinclusive thought (Eysenck, 1995), and even clang associations (i.e., associations according to sound rather than meaning; Hadamard, 1945). These associative processes do not have to be described in detail to draw the following pair of inferences.

First, none of the named processes can be said to generate sighted associations. That is, in no instance would we expect the response probabilities to be coupled with the respective utilities. In the case of the Remote Associates Test, for instance, the associations that have the highest utilities relative to the target will have among the lowest probabilities of retrieval. This decoupling is precisely what renders them "remote" (e.g., "working" is not the first word to come to mind when presented with either "railroad," "girl," or "class," nor the very first word that is retrieved when presented with all three; Mednick, 1962). Likewise, divergent thinking only becomes useful in problem solving to the extent that it yields alternatives that would not be otherwise examined, such as making a pendulum using pliers. It is notable that when Maier (1931) directly instructed his participants to solve the two strings problem using the pliers, the first response was often to employ them as tongs, and most participants could not imagine using the pliers as a weight until after the experimenter gave them a hint (viz., by "accidentally" making one cord sway). In fact, if the thinking process produced alternative uses with probabilities coupled to their solution utilities, the process would be identified as convergent rather than divergent thinking (Guilford, 1967). If the goal was to screw in a screw and the participants were offered the choice between a screwdriver and a sledgehammer, then divergent thinking becomes unnecessary.

Second, when problems are unusually difficult, complex, and/or novel, it is probable that more than one associative process will be evoked prior to successful solution. Yet if two or more processes are elicited, then these processes are often distinct enough to activate variable associative responses to a given stimulus situation. These disparities are important to the extent that creativity depends on spreading activation proceeding from problem input (see, e.g., Langley & Jones, 1988; Mandler, 1995). Activation may then follow two or more associative pathways resulting from two or more of these associative mechanisms. As this activation expands, some pathways may intersect at certain nodes in the semantic network, nodes that may or may not offer a solution, while other pathways may persist in their isolated advance, sometimes leading to a solution but more frequently heading into a cul-de-sac. Hence, we can conceive of variable utilities for two alternative associative pathways: Activation paths X and Y might have utilities $u(X) > u(Y)$. At the same time, it is very likely that these alternative pathways would have different associative strengths. In the extreme case, they might be $p(X) < p(Y)$ in a kind first-will-be-last and last-will-be-first situation (i.e., the most unlikely route is the one that gets you there).

In any event, so long as the alternative paths do not match in relative probabilities and utilities, then the associative processes are decoupled and hence partly blind by definition. Even if the two sets of parameters do closely compare, they could only count as coupled if the relative utilities directly implied the same relative associative strengths. This linkage might happen if the creative individual had somehow learned that remote associations work best for problem type *A*, Janusian associations for problem type *B*, clang associations for problem type *C*, and so forth, and evoked the corresponding associative response to fit the input. Given how many of these processes operate unconsciously or automatically, rather than consciously and deliberately, this type of expertise would seem highly implausible in occasions of authentic creativity (see, e.g., Rothenberg, 1983). Instead, they would merely provide spontaneous ideational variants that are largely if not entirely independent of the problem conditions (see also Martindale, 1995).

To sum up, the separate associative processes not only feature some degree of blindness, but also their collective operation when two or more processes are elicited must also display blindness to some extent.

2. Defocused attention. The former argument says that once the mind is stimulated with a given problem, spreading activation may expand along two or more routes with associative strengths that are decoupled from their probable success in leading to a solution. Yet it also must be recognized that the creative intellect is also vulnerable to the vicissitudes of continued stimulation from the external world. More specifically, it has long been known that creativity is positively associated with defocused attention (Eysenck, 1995; Kasof, 1997; Mendelsohn, 1976; cf. Zabelina & Robinson, 2010), and this correlation has received additional support from more recent research on the relation between creativity and reduced latent inhibition (Carson, Peterson, & Higgins, 2003; Peterson & Carson, 2000; Kéri, 2011). Creative persons are more likely to respond to extraneous stimuli even when those stimuli have been proven irrelevant. This attentional proclivity departs diametrically from what is displayed by domain experts who are very proficient at ignoring information deemed irrelevant to the problem at hand (see also Ansburg & Hill, 2003). Furthermore, the extraneous sensory input resulting from defocused attention is likely to prime the ongoing associative process in unpredictable ways, leading it down new pathways that might not otherwise be pursued. This would enhance rather than diminish the decoupling of the associative strengths from their corresponding utilities.

This complex and volatile interplay between associative richness and defocused attention is especially central during what Wallas (1926) famously identified as the incubation phase of the creative process. After realizing that a problem cannot be readily solved despite repeated attacks (i.e., the spreading activation dead-ends), the creator will frequently move to other tasks, including the activities of everyday life (e.g., "the bath, the bed, and the buss" in Boden, 2004, p. 25). During this interval, the individual is involuntarily exposed to a much greater variety of unrelated stimuli that can prime various associations. Although most of these associations will still lead nowhere, and thus can be counted as blind variants emerging at the unconscious level, one accidental event may lead the associative process in a more fruitful direction. The archetypal example is the Eureka experience that Archimedes had taking a bath (i.e., the mathematician had no advanced rationale for believing that the overflowing water would solve the problem on which he had been working). Laboratory experiments on insight have lent some support to the involvement of such "opportunistic assimilation" (e.g., Seifert, Meyer, Davidson, Patalano & Yaniv, 1995). Nonetheless, it must be emphasized that the cognitive susceptibility to extraneous input would be enhanced for individuals who simultaneously feature both associative richness and defocused attention.

3. Behavioral tinkering. The associative and attentional processes just mentioned take place inside the head. But sometimes creativity and discovery take place outside the head, the ideational trials assuming external form. Picasso's *Guernica* sketches provide a case in point. In the same way, a composer may sit at the piano and just start playing around with various note combinations until something interesting comes up that is worth expansion. Other times the overt behavior will involve some variety of behavioral tinkering, a particularly common practice in science and technology (Kantorovich, 1993). A famous illustration is Watson's (1968) route to discovering the DNA code:

> I spent the rest of the afternoon cutting accurate representations of the bases out of stiff cardboard . . . . [Later] I quickly cleared away the papers from my desk top so that I would have a large, flat surface on which to form pairs of bases held together by hydrogen bonds. Though I initially went back to my like-with-like prejudices, I saw all too well that they led nowhere . . . . [I] began shifting the bases in and out of various other pairing possibilities. Suddenly I became aware that an adenine-thymine pair held together by two hydrogen bonds was identical in shape to a guanine-cytosine pair held together by at least two hydrogen bonds (p. 123).

What is enlightening in this report is that Watson began his tinkering by testing the pairings of adenine-adenine, cytocine-cytocine, and so forth, even though he should have known better (viz., because of Chargaff's rule). Only after fumbling around with various possible hydrogen bonds was he able to discover that (a) adenine joined with thymine and guanine with cytocine and (b) the two sets of combined molecules had the same overall form, permitting them to unite the two spines of the double helix with uniform spacing.

Naturally, such tinkering can also take place inside the heads of those creators who enjoy the capacity for vivid visual imagery. Einstein speaks of visual "combinatorial play" which he viewed as "the essential feature in productive thought" (Hadamard, 1945, p. 142). Many of his famed Gedanken (thought) experiments were conceived in this way. Sometimes the creator can even tinker with visual representations that would be impractical in the external world (e.g., the "homospatial" thinking described by Rothenberg, 1987). At age 16, Einstein tried to visualize of what would happen if he were to ride along with a light beam. A decade later, this unquestionably imaginary visualization led to his special theory of relativity, which argues that such an act is unrealistic because the speed of light is always the same to all observers no matter what their reference frames.

4. Heuristic search. Newell and Simon (1972; see also Newell, Shaw, & Simon, 1958) introduced a classic model of human problem solving that has been developed into a more general theory of creativity and discovery (e.g., Simon, 1986), especially in the sciences (Klahr, 2000; Klahr & Simon, 1999). Indeed, the Newell-Simon tradition helped provide the basis for the discovery programs discussed earlier in this article. This perspective makes a critical distinction between two approaches to problem solving: algorithmic and heuristic methods. Algorithmic methods represent precise step-by-step procedures that pretty much guarantee a solution, whereas heuristic methods are more indefinite "rules of thumb" that may or may not lead to a solution. Given this contrast, algorithms can be referred to as “strong” methods, whereas heuristics represent “weak” methods (Klahr, 2000). Moreover, whereas algorithmic methods are most often domain specific in application, heuristic methods can be applied to a wide range of problems. Such heuristic methods include hill climbing (steepest ascent), means-end analysis, working backward, analogy, and trial-and-error.

Although the very last heuristic method is the only one that explicitly represents a generate-and-test or BV procedure, it should be evident that all heuristic methods have implicit blindness associated with their application (Simonton, 2003b). For example, although analogical thinking can prove a very useful heuristic tool, it is not always immediately apparent which of two possible analogies will work best (e.g., light as a particle or wave). There may be no other choice but to try them out one by one, working out the proper correspondences (e.g., what is “waving” if light is a wave), and then see which analogy leads to a more insightful fit to the target phenomenon (e.g., how it handles interference). In this situation, we have definite decoupling (see the MAC/FAC or “many are called but few are chosen” model of analogical reasoning; Gentner, 1998).

Of course, problem solvers will endeavor to use algorithmic methods whenever doable, but frequently they will have to fall back on a more heuristic search through the various possibilities. The reason for the latter course of action is that problems themselves may vary from well-defined problems with clear-cut means and goals to ill-defined problems where both the goals and the means are vague and insufficiently determined. Examples of the latter include (a) creating a modernist painting that dramatically depicts the horrors of a wartime atrocity and (b) inventing a theory that reconciles an esoteric contradiction between Maxwellian electromagnetic theory and Newtonian mechanics. The former problem yielded Picasso’s *Guernica* while the latter inspired Einstein’s special theory of relativity.

The forgoing can be recast in BVSR terms. For well-defined problems, the algorithmic methods are strongly coupled to the most likely solution. Given the equation $2x^2 + 5x - 3 = 0$ and the goal to find the two roots, the answer is supplied without fail via the quadratic formula. But as the problems become more ill-defined, not only must the person rely increasingly on weak heuristic methods that do not promise a proper solution, but it also becomes ever less evident what are the best heuristic methods to try out first. That ambiguity elevates the trial-and-error heuristic to the status of a superordinate metaheuristic (Simonton, 2004). The creator may have no other option than to generate-and-test all available heuristic methods without any assurance that even one option will actually work. Because heuristic search has thereby become decoupled from the utilities for various heuristics with respect to a given problem, each applied heuristic method constitutes a blind ideational variant at a metacognitive level of operation.

Associative richness, defocused attention, behavioral tinkering, and heuristic search all embody rather different processes. Some operate largely at the involuntary and unconscious level while others are more mindful and intentional in application. Heuristic searches certainly fall in the latter category. Yet as the above analysis indicates, even the latter can engender BVs. Newell, Shaw, and Simon (1962) themselves indicated long ago, “In spite of the primitive character of trial-and-error processes, they bulk very large in highly creative problem-solving; in fact, at the upper end of the range of problem difficulty there is likely to be a positive correlation between creativity and the use of trial-and-error generators” (pp. 72–73). As a result, it is not necessary to claim that the cognitive mechanisms supporting BV presuppose some form of “hidden chaos” or other exceptional process, as some have argued (e.g., Kronfeldner, 2010; Weisberg, 2006). Indeed, because combinatorial procedures that are both explicit and systematic can still yield BVs, Campbell’s (1960) model requires nothing either clandestine or chaotic.

Theoretical Implications

The foregoing definitions and illustrations now permit us to specify some important implications about BVSR creativity and discovery. The implications concern domain expertise, ideational randomness, analogical equivalence, and personal volition. As stated earlier, these four implications are often gotten wrong by Campbell’s (1960) critics.

Domain Expertise

Domain-specific expertise plays a large part in BVSR. Without doubt, such expertise has a major role in determining variant utilities—especially if little-c or P-creativity is to convert to Big-C or H-creativity. If others in the know find the idea useless, however novel and surprising, then the creator, discoverer, or inventor is not going to go very far. Despite that easy admission, the variation side of BVSR has a more equivocal connection with domain-specific expertise. In fact, BV opponents often claim that blindness is inconsistent with such expertise (e.g., Ericsson, 1999; Kronfeldner, 2010). If creators know what they are doing, then the ideational variants will be sighted rather than blind. This contrast is frequently stated in either-or terms as if any application of expertise to solve a problem automatically excludes the operation of blindness (e.g., Kronfeldner, 2010; cf. Kozbelt, 2008). However, according to the definition of sighted and BVs given earlier, this dichotomy is specious. Blindness is a property of *possible* variants, not variants that are considered impossible. For instance, in addition to bona fide variants X and Y there might exist purely hypothetical variants W and Z, but the latter pair might have been altogether excluded from consideration by previously acquired knowledge. That is, $p(W) = p(Z) = 0$ precisely because $u(W) = u(Z) = 0$ (e.g., because they both violate a fundamental law of physics). Even so, the exclusion of W and Z does not instantly affect the coupling or decoupling of the respective probabilities and utilities for X and Y. This lack of a lateral effect holds even if it should happen that the absolute probabilities for X and Y are changed after explicitly excluding W and Z (see also Simonton, in press).

A priori reductions in possible variants are usually explicit in BV mechanisms or processes that are blind by intention. A radar scan is seldom spherical (i.e., all directions) but rather is restricted to a circular band along the horizon, or perhaps even just to a sector of the horizon, as in air-defense systems. A search grid is not dropped down anywhere randomly, but rather is imposed over an area that is most likely to yield discoveries (e.g., early hominids are found in specific geological formations of East Africa, never anywhere in the Americas). Even the rediscovery of Kepler’s

Third Law confined the mathematical functions (integral powers) to just that subset that would prove most compatible with the Kepler's First and Second Laws (which concerned ellipses and areas, respectively). In spite of these restrictions, the subsequent systematic combinatorial variants remain decoupled and hence blind.

Similarly, in genuine acts of creativity, domain-specific expertise is invariably used to narrow the range of possible variants. Once Picasso decided on doing a painting that depicts the brutality of war, certain figural elements were immediately excluded as clearly inappropriate, such as erotic nudes (Doyle, 2008). Likewise, when Watson (1968) tinkered with his cardboard models of the DNA bases, he not only knew the specific structures of the four bases (in their proper tautomeric forms after a false start), but he also realized the need to focus his attention on the viable hydrogen bonds that might connect them in congruent pairs. Even so, neither Picasso nor Watson had sufficient expertise to bypass the production of blind ideational variants. The artist still had to sketch and the scientist still had to tinker.

Recall what was said earlier about heuristic searches. Whenever possible, we try to solve problems using algorithmic methods. Those methods constitute an integral part of our domain-specific expertise. Still, those same methods often fail us when we are confronted with ill-defined problems, obliging us to fall back on unreliable heuristic methods—including the all-inclusive trial-and-error metaheuristic. We may even be obliged to enter an incubation period in which spreading activation and defocused attention operate in a less conscious and less deliberate fashion. Yet we do not turn to these weak methods because we prefer them to the strong methods. Rather, we resort to them because our domain-specific knowledge and skill was not able to reduce the number of possible variants to just one. BV begins where domain expertise ends (cf. Nickles, 2003). BV enters by default, not by preference.

Nonetheless, prior knowledge can also impose too many restrictions on the BV process. Some assumed impossible variants should actually be considered possible. Perhaps $p(Z) = 0$ even though $u(Z) = 1$ were that variant generated so that it could be selected (cf. Type 4 and 5 variants in Simonton, in press). This possibility provides another reason why reduced latent inhibition can prove so useful to creativity (Carson et al., 2003; Eysenck, 1995; Kéri, 2011; Peterson & Carson, 2000). If expertise excludes the supposedly irrelevant according to accumulated experience, but the apparently irrelevant is actually relevant in this circumstance (such as using pliers as a pendulum weight in the two strings problem), then defocused attention should be an asset rather than a deficit.

Augmenting this dispositional advantage, highly creative individuals often will have developmental backgrounds that encourage them to "think outside the box." Campbell (1960) observed that "persons who have been uprooted from traditional cultures, or who have been thoroughly exposed to two or more cultures, seem to have the advantage in the range of hypotheses they are apt to consider, and through this means, in the frequency of creative innovation" (p. 391; for empirical support, see Leung, Maddux, Galinsky, & Chiu, 2008). In a similar vein, Kuhn (1970) claimed that scientists who launch major revolutions are frequently "very new to the field whose paradigm they change" because these very individuals "are particularly likely to see that these rules no longer define a playable game and to conceive another set that can replace them" (p. 90; for recent evidence, see Jeppesen & Lakhani, 2010; Simonton, 1984b). Indeed, domain-specific expertise can often accumulate to the point that it interferes with exceptional creativity (Simonton, 2000a; see also Frensch & Sternberg, 1989). This fact may help explain why a creator's best work is very rarely his or her last work (Simonton, 1997). If expertise were the deciding factor, then the final offering should be a culmination, not a letdown. This ambivalent relation between expertise and creativity also accounts for why highly creative people tend to be very versatile and to have broad interests (Cassandro, 1998; Cassandro & Simonton, 2010; Gough, 1979; Root-Bernstein, Bernstein, & Garnier, 1995; Root-Bernstein et al., 2008; Simonton, 1976, 1984a; White, 1931). If narrow expertise were the central factor, then those who had interests and skills narrowly confined to their chosen domain should be the most creative.

Ideational Randomness

Probably no other criticism has been more misguided than that based on the assumption that BVs must be random to be blind (e.g., Russ, 1999; Schooler & Dougal, 1999). Sometimes this misleading argument is expressed as an apparent reductio ad absurdum: The impossibility of a room full of monkeys ever typing out the works of William Shakespeare (Schooler & Dougal, 1999; cf. Martindale, 1995). Yet as noted earlier, Campbell's (1960) BVSR only requires blindness, not randomness. Nothing is less random than a radar sweep. The same holds for other systematic combinatorial processes. For this reason, Popper regarded Campbell's (1960) "idea of the "blindness" of trials in a trial-and-error movement as an important step beyond the mistaken idea of random trials" (quoted in Kim, 2001, p. 103). The same principle applies to divergent thinking, remote associations, and other cognitive processes involved in creativity. As long as the probabilities of any generated responses are decoupled from their utilities, the responses are blind without the necessity of being random. In the two string problem, if p(pliers-as-tongs) $>>$ p(pliers-as-pendulum) even though u(pliers-as-tongs) $<<$ u(pliers-as-pendulum), then we have a pair of partially blind but not random variants.

Despite the above precaution, it remains true that the creative process often operates *as if* it were generating random variants. That is probably why, as mentioned earlier, computer programs that most successfully simulate or exhibit creativity tend to rely on some stochastic mechanism (Boden, 2004). This as-if randomness also explains why combinatorial models have proven so successful in explicating many key features of creativity, from productivity across the life span to the occurrence of multiple discoveries (Simonton, 2010a). Even human creativity tends to be stimulated when individuals undergo exposure to novel, unpredictable, incongruous, or even random stimuli (Finke, Ward, & Smith, 1992; Proctor, 1993; Rothenberg, 1986; Sobel & Rothenberg, 1980; Wan & Chiu, 2002). In effect, such sensory input operates as a form of experimentally induced defocused attention and remote association, activating associative pathways that would have otherwise remained dormant. Although most of the resulting spreading activation will prove abortive, one or another path may eventually lead to the problem's solution. At bottom, the attentional and associative processes involved are no different to what normally happens during the incubation period when the creator is exposed to the haphazard influx of everyday events. Randomness is not required for blindness, but events that seem random can stimulate effective blindness.

Analogical Equivalence

Campbell's, 1960 article includes not a single reference to any of Charles Darwin's writings, and he mentions Darwin's name only twice in the text, both times in a rather peripheral manner. The first mention was simply to note that the antecedents of the BVSR model of creativity can be found in Alexander Bain's (1855/1977) *The Senses and the Intellect*, a work published four years before Darwin's statement of spontaneous variation and natural selection. As Bain had it, creativity is "so much dependent upon chance [that] the only hope of success is to multiply the chances by multiplying the experiments" (p. 597). Not only does "chance" imply variant blindness but also "multiplying the experiments" implies variant superfluity. In his article, Campbell made it evident that he considered BVSR as the generic process with biological evolution, perception and learning, and creative thinking as specific instantiations (see also Campbell, 1956). Contrary to certain critics (e.g., Kronfeldner, 2010), Campbell certainly did not predicate the case for BVSR on a close-fitting Darwinian analogy (see also Hull, 2001; cf. Martindale, 2009).[6]

Admittedly, when Campbell (1974a) later devoted so much time to developing his evolutionary epistemology, it might seem natural to think of his enterprise as some Darwinian venture. Yet Campbell avoided referring to his position as Darwinian, leaving it to others to explicitly link creativity with that adjective. As observed before, Simonton was perhaps the main agent in linking the two terms, starting with a chapter published just 3 years before Campbell's death (Simonton, 1993). More critical, perhaps, Darwinism seems to have become a hot topic during the late 1980s and early 1990s, at least as evidenced by the publications that emerged during this decade (e.g., Dawkins, 1989; Dennett, 1995; Edelman, 1987; Perkins, 1994; Ruse, 1986; Söderqvist, 1994). Darwinism popped up everywhere, from antibody formation and neurological development to operant conditioning and sociocultural evolution (Cziko, 1995, 2001). It may have seemed natural to include creativity in these extrapolations (e.g., Perkins, 1994; Simonton, 1993). This inclusion becomes especially likely given that creative thought occupies a place roughly midway between operant conditioning and sociocultural evolution.

A regrettable consequence of this implicit zeitgeist was apparently an increased emphasis on establishing a tight analogy between biological evolution and human creativity. An instance was Stein and Lipton's (1989) attempt to establish that ideational variations are "guided" in a manner analogous to the preadaptations in biological evolution. Such fine-grained analogies are doomed to fail (Sternberg, 1999; Kronfeldner, 2010; Ruse, 1986; Thagard, 1988). In the first place, whereas variational blindness in biological evolution is absolute, mutation and genetic recombination being totally unguided by fitness, BV in human creativity has the advantage that it can exploit domain-specific expertise whenever possible (cf. Kronfeldner, 2010). Hence, ideational variations in creativity and discovery take place along a continuum from wholly sighted to entirely blind (see Simonton, in press, for a potential metric). Furthermore, the two manifestations of variation-selection differ according to whether selection is mostly (a) simultaneous or sequential and (b) external or internal. The two forms also vary in the processes underlying either variation (e.g., stochastic vs. systematic) and retention (e.g., genes vs. memory). Finally, evolutionary phenomena form a nested series (Campbell, 1974a; Dennett, 1995; see also Kim, 2001). As Skinner (1953) wrote, "where inherited behavior leaves off, the inherited modifiability of the process of conditioning takes over" (p. 83). Yet where conditioning or learning leaves off—as reflected in the organism's acquired expertise—creative problem solving appears. The nested nature of variation-selection phenomena necessarily undermines any attempt to reduce them to a single isomorphic structure.

Personal Volition

Once BVSR opponents recognize that Campbell's position is not contingent on an analogy with Darwin's theory of biological evolution then other criticisms based on presumed disanalogies become irrelevant. For example, some critics argue that creative individuals are engaged in highly purposeful behavior, unlike the (largely) mindless Darwinian organisms (e.g., Doyle, 2008; Sternberg, 1999). As Sternberg (1999) expressed it, "creativity is forward-looking and intentional, while evolution is not" (p. 357). However, if the BVSR account of creativity is conceived as originating with Bain (1855/1977) rather than with Darwin, then this complaint is off the mark. In fact, although effectively ignoring Darwin, Campbell (1960) quoted Bain at length to emphasize the extreme importance of interest, curiosity, drive, energy, and determination in the creative process. Bain wrote, for instance, "The number of trials necessary to arrive at a new construction is commonly so great that without something of an affection or fascination for the subject one grows weary of the task. This is the *emotional* condition of originality of mind in any department" (italics in original; p. 593). Later Bain stressed the requisite of "an Active turn, or profuseness of energy, put forth in trials of all kinds on the chance of making lucky hits" (p. 595). Hence, as Bain has it, the creator's dependence on trial-and-error requires more volition, more purpose, than is needed for routine problem solving. The latter can often become virtually automatic (see also Simonton, 2008, for further discussion).

What BVSR theory does deny is that such willful behavior can allow the creator to bypass the production of blind thought trials. As the logician and economist Jevons (1877/1900) noted with respect to scientific creativity:

> it would be an error to suppose that the great discoverer seizes at once upon the truth, or has any unerring method of divining it. In all probability the errors of the great mind exceed in number those of the less vigorous one. Fertility of imagination and abundance of guesses at truth are among the first requisites of discovery; but the erroneous guesses must be many times as numerous as those that prove well founded. The weakest analogies, the most whimsical notions, the most apparently absurd theories, may pass through the teeming brain, and no record remain of more than the hundredth part. (p. 577)

[6] Ironically, while Darwin was working on *Origin of Species*, he had been advised by a friend to read Bain's book. Although he purchased a copy for his private library, he never got around to reading it (Simonton, 2010c). If he had done so, there might be no need to write this paragraph!

Thus, Faraday no doubt deeply desired to solve the problems he set before himself, but his conjectures and hypotheses still had to suffer a 90% rejection rate. Watson had the likely prospect of a Nobel Prize to keep him highly motivated, but he still had to tinker around with cardboard models. And what holds in the sciences becomes even more apparent in the arts. Picasso certainly wanted *Guernica* to be a great painting, but he still had to sketch out numerous false starts and engage in apparently fruitless experiments. Beethoven undoubtedly sought a climactic ending to the Fifth's first movement, but still had to backtrack from a longer to a shorter coda. Creators can motivate themselves to initiate and persist in BV, but they cannot coerce BV to create on demand.

On the contrary, if the drive is too excessive, it can prove counterproductive by increasing the individual's arousal level beyond the optimal level for creative problem solving. Increased arousal will narrow the range of attention, accentuating the generation probabilities of low utility variants while decreasing the emission probabilities of high utility variants (Martindale, 1995; Simonton & Damian, in press). The creator or discoverer will then have no other choice but to enter an incubation period in which the desire for a solution is placed on the back burner. Sometimes attaining a goal is only possible by temporarily suspending the attempt to achieve the goal.[7]

Conclusion

Campbell's BVSR model has undergone considerable theoretical and empirical development since 1960. In the current article, I have tried to strengthen the theoretical argument by providing a more precise definition of what constitutes a BV. This definition then was reinforced by specific identification criteria that establish the extent to which blind variants are involved in creativity and discovery. These enhancements then had significant implications regarding four central questions regarding domain expertise, ideational randomness, analogical equivalence, and personal volition. All told, these developments reinforce the case on behalf of BVSR theory.

The last assertion does not mean that the theory now stands complete. Quite the contrary, several matters require additional attention. For instance, one especially urgent question involves the relative degree of blindness and sightedness in any given problem-solving episode. Once we accept that thought trials can incorporate variable amounts of these two qualities (e.g., chance vs. expertise), then we should measure the episode's standing on a bipolar blindness-sightedness dimension. Although Simonton (in press) has suggested a potential metric, he has yet to apply it to specific cases. Such applications could prove very valuable in (a) contrasting breakthrough discoveries with less innovative ideas and (b) comparing representative episodes in different creative domains (cf. Simonton, 2009b). This proposed metric might also enable us to place our earlier illustrations of explicit and implicit BVSR on the same scale. We could then directly compare the relative blindness and sightedness of, say, radar scans and search grids, genetic algorithms, BACON's rediscovery of Kepler's Third Law, Picasso's creation of *Guernica*, Beethoven's composition of his Fifth Symphony, and Watson's discovery of the DNA base pairs. Those potential quantitative comparisons are both legitimate and provocative.

In short, the evolution of Campbell's (1960) BVSR model is not yet over. It is hoped that this article has shown that the theory may be worth pursuing for another 50 years if not more. It still holds considerable promise as a truly comprehensive and coherent perspective on creativity and discovery in the sciences and the arts. In reality, BVSR has no present-day rival in terms of both inclusiveness and precision.

[7] Given that the question of personal volition is intimately linked with the notion of free will, it is worth noting that William James (1880) was not only one of the earliest advocates of a BVSR-type theory of creativity (cf. Campbell, 1974a), but he also put forward a BVSR-like theory of free will. The latter also consisted of two stages: "first 'free' random generation of alternative possibilities, followed by 'willed' adequately determined decisions consistent with character, values, and desires" (Doyle, 2010, p. 1). Although both of these ideas can be attributed to the direct influence of Charles Darwin's variation-selection theory, we know that James had read Bain (1855/1977), and thereby James was definitely exposed to an early version of a "chance-generation selective-retention theory" of creativity that has an uncanny resemblance with the Jamesian concept of free will.

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