

Improbable Creativity

Alan Dorin and Kevin B. Korb

Abstract

We begin with a number of basic facts about creativity and a brief history of the idea. These provide criteria that any definition of the term should meet and help guide us to a new definition of *creativity*. This definition is independent of cultural appropriateness or the perceived value of creative objects, ideas which have encumbered previous investigations. We briefly defend our definition against some plausible objections and then explore the ways in which this new definition differs from alternative views, by improving upon them.

Keywords: Creativity, mechanism, novelty, complexity, representation.

God is the perfect poet — Robert Browning

1 The Facts about Creativity

Creativity was originally the sole domain of the gods. Subsequently, humans have been the beneficiaries of this Promethean gift, but there has been little consensus on what to make of it. There is *some* consensus in the literature on creativity: that we humans are sometimes creative. In trying to grapple with the concept so as to find an exact definition of it there has been no consensus. Nevertheless, there are other facts which are widely agreed to, either explicitly or implicitly in the way the word ‘creative’ is used. We list five of the most basic and agreeable here.

Basic Facts about Creativity

Fact 1 *Humans may be creative.*

Fact 2 *Processes, solutions to problems and works of art may all be creative.*

Viewing humans as processes, we could, of course, combine Facts 1 and 2; however, humans on the whole being vain when not being creative, they usually prefer to consider the facts about themselves as separate, primary or even unique. The main point we infer from these facts is just that creativity inheres in two varieties of entities: objects, abstract or concrete, and the processes that produce them.

Fact 3 *Duplication is uncreative; novelty is essential.*

Originality or novelty is at the center of all dictionary definitions of ‘creativity’. It follows immediately that the creativity of works and processes is *relative*, relative to their own histories and the socio-cultural context in which they occur. For example, the original discovery of the Pythagorean theorem was creative, as was its use to demonstrate the existence of irrationals. But today these are schoolboy exercises for the bored, rather than innovations. Creativity eats its own tail.

Fact 4 *Creativity comes in degrees, from the exceedingly high, down to mediocrity and further to non-existence.*

The dullard student copying the creative master is readily distinguished from the original, simply by removing the creative source and observing the results. The dullard, lacking guidance, cannot avoid being dull.

Fact 5 *It is possible to be mistaken about whether or not an act is creative.*

This actually follows from Fact 3, since the context in which a work is produced may be unknown or mistaken. We separate it out as a new Fact because of its importance.

Corollary 1 *Creativity may go unrecognised for any period of time.*

This is one of the most remarked upon facts of creativity, with many hundreds of famous examples in the arts and sciences available for illustration.

These are the fundamental facts about creativity so far as we can tell. That is, these facts are very widely taken to be either definitive of the concept or generally true in its application. They therefore provide criteria against which we can test any proffered definition, including our own. Other, less certain, ideas about creativity may then be examined in the light of definitions which do justice to the fundamental facts.

Opinions about Creativity

Opinion 1 *Creative processes and objects must have high value.*

While not figuring in any dictionary definition, the tying of value to creativity figures prominently in the recent cognitive science literature. We consider this to be a mistake and shall explain why below.

Opinion 2 *Creativity is a unique, perhaps defining, characteristic of humans, elevating us above other life forms.*

This view finds its origins in early religious ideas about creativity. The idea was consolidated by philosophers such as Descartes, who thought human cognition incapable of explanation in mechanical terms, unlike that of all other animals (Descartes, 2006, Part V). Nevertheless, we consider this Opinion to be both false and refuted. There are many other life forms which demonstrate creative behavior, behavior which would command acknowledgement even from those elevated persons who subscribe to this Opinion, were but the source of the behavior concealed from view.

Opinion 3 *Computers can be creative (Boden, 1999, 2004; Cohen, 2002).*

Opinion 4 *Biological evolution is creative (Bentley, 2002).*

We endorse both of these latter Opinions, but leave discussion of them to future work.

2 A Brief History of Creativity

2.1 Early Views

Our aim in this section is to give a brief history of the term and the concept of creativity in order to demonstrate the degree to which the idea and the meaning of creativity has changed over the years. Tatarkiewicz provides an essay on the topic from which we develop our own short narrative (Tatarkiewicz, 1980, pp. 244-265). (For an alternative view see Albert and Runco, 1999.)

Plato describes a demiurge in his dialogue *The Timeaus* who was responsible for constructing the universe. The demiurge was an “architect”, transforming existent matter in accordance with pre-existing ideals. To works of sculpture and paintings such as a human might make, Plato applied the term *techne* (in *The Republic* and other dialogues). Artistic works of this kind are imitations either of Ideal or actual forms, made in skillful accordance with natural laws. According to Plato, the poet, working with words and verse, rather than painted or sculpted representations of objects, had the freedom to invent things that did not exist previously — he engaged in poiesis (see *The Symposium*).

The philosopher-poet Lucretius wrote (c. 50 BCE):

But only Nature’s aspect and her law,
Which, teaching us, hath this exordium:
Nothing from nothing ever yet was born.

The terms *creatio* (a creator) and *creare* (to create), the progenitors of the word we employ to this day in English, arose at this time. Yet Lucretius’ philosophy itself forbade any kind of creative activity in which something arises from nothing.

The Mediaeval period saw the emergence of ‘*creatio ex nihilo*’ bound tightly to the Christian philosophers’ conviction that their god had created the universe in this way. This newly designated creative act could not be replicated by humankind; it was reserved solely for God. St. Augustine and Pseudo-Dionysius were two proponents of this view, surmising that artists were mere imitators of God’s creation: nature’s perfection (Tatarkiewicz, p247).

The Renaissance saw a change in thinking. Writers such as Vasari (1965) felt that Man could improve upon God’s creation. Thus, whilst they may take nature as inspiration, their expansion upon its oeuvre with their own, allowed them the freedom to conquer it. Similar ideas appeared at the time in discussions surrounding poetry, until finally the Polish writer Sarbiewski (1595-1640) stated that the poet *de novo creari . . . instar Dei*, the poet creates anew in the manner of God (Sarbiewski, 1954).

It was only in the late 17th and early 18th centuries that some theorists raised the status of visual artists from mere imitators to creators. The debate continued through the Enlightenment as to whether or not creation was solely a domain of God. By the 19th century, art had finally claimed creativity as its exclusive domain. In the 20th century, the term had become more broadly applied, even reaching into the sciences and engineering, until finally it landed across fields as ungodly as marketing and business decision making. The requirement that a creator was somebody who made “something from nothing” was dropped, and instead the manufacture of novelty became central.

2.2 The Cognitive Science of Creation

The introduction of modern computers in the nineteen fifties led directly to the invention of cognitive psychology and, more generally, cognitive science. The central metaphor of cognitive

science is thought-as-computation, and its central quest is the search for artificial intelligence (AI). Those who believe in the possibility of strong AI — a genuinely intelligent artifact — must necessarily also believe in the possibility of an algorithm that exhibits creativity and so in the possibility of a computational analysis of creativity.

The potential for computers to generate works that, when produced by humans are considered to be creative, has been widely addressed. It is well beyond the present scope to delve into this area in detail. A couple of well-known examples include Harold Cohen's AARON software which explores the potential for machine creativity in the visual arts. Cohen uses the term creativity "to refer to the ability of the individual — human right now, program potentially — to move forward, to develop, to introduce new material, whatever those rather imprecise terms mean." Cohen does not label his own software AARON as creative, since he feels that its progress has been due to him, the programmer, and not achieved autonomously. David Cope's Experiments in Musical Intelligence (EMI) / Emmy, is a similar attempt to match the creative activity of humans, in this case composers, with software. Cope gives many examples in which, "composers create music by mixing such signatures and using *recombinancy*, or the recombination of elements found in other of their works and in the music of other composers" (Cope, 1996, Chapter 1). Other examples of software targeting creativity exist in the domains of mathematics (notably with the work of Doug Lenat; cf. Lenat, 1983), logic (Colton, 2001), and scientific discovery (Langley et al., 1987). Some researchers, however, reject claims that these examples exhibit creativity. Rowe and Partridge (1993) critique many attempts to generate computational creativity, including Lenat's. Hofstadter (1995, p. 468) complains that, although AARON draws human forms, it has no "understanding" of what it is to be human and so cannot be creative. This complaint echoes the more general worries about the prospects of artificial intelligence frequently and strongly put by John Searle (Searle, 1980), the inventor of the term "strong AI". According to Searle, any system lacking understanding, and indeed consciousness, cannot hope to exhibit intelligence, let alone creative intelligence (Searle, 1992).

Although we reject these views of Hofstadter and Searle (see, e.g., Korb, 1991), here we shall simply address artificial creativity in the sense of weak AI: we shall assume it will be good enough should cognitive scientists be able to reproduce convincingly creative *behavior*, and so passing some Turing Test for creativity. If this does not pass some deeper test for creativity, failing to yield also a deep account of creative consciousness, then we shall regret that limitation, but we shall not consider that any defect in its account of creativity to the depth that it actually reaches. Such a pseudo-creative artifact would nevertheless have to be both an outstanding achievement and, at least implicitly, a profound account of creativity.

2.3 Definitions of Creativity

Before attempting our own definition of "creativity" we shall canvass a few recent alternative definitions.

Definition 1 (Creativity) *Creativity is the ability to produce work that is both novel (i.e., original, unexpected) and appropriate (i.e., useful, adaptive concerning task constraints).*

Very similar definitions to this one are given by Ochse (1990) and many others. Perhaps the most cited such definition is that of Boden:

Definition 2 (Creativity) *Creativity is the ability to come up with ideas or artefacts that are (a) new, (b) surprising and (c) valuable (Boden, 2004, p. 1).*

Boden refines this definition in various ways.

- (a) There are two ways in which something might be new: (i) *p(ychological)-creativity* introduces something that is new to the person who devised the idea or artefact, but may be previously known to others, and (ii) *h(istorical)-creativity* is new to the whole of history.
- (b) Boden finds three distinct ways in which something might be surprising: (i) it is unfamiliar or unlikely; (ii) it unexpectedly fits into a class of things you hadn't realised it fitted into; (iii) it is actually something you thought was impossible.
- (c) Regarding her third criterion for creativity, value, Boden is certain that there are more ways in which this might occur than anybody could ever list.

Csikszentmihalyi (1999a,b) applies a definition very much like Boden's, in which novelty and value are essential to creativity. For him, the novelty of an idea is relative to the ideas previously active in a domain. Although Csikszentmihalyi doesn't tackle value directly (like Boden, steering clear of this quagmire), he takes value to be determined by a group of experts who act as the gate-keepers of knowledge in a domain. It is their role to determine what should be admitted and what repelled, and so determining how the domain develops. Those ideas they allow within are by definition creative.

3 A New Definition of Creativity

Definition 3 (Representation) *Representations are the bearers of meaning, expressing, denoting or imitating something other than themselves (van Gulick, 1980).*

All ideas, concepts, algorithms, procedures, theories, patterns, etc. that we deal with are represented by us and to us, whether through language or otherwise. Note that representations are *instances* or *tokens* — e.g., marks on paper — rather than abstract objects, even when what they are expressing is abstract.

Definition 4 (Pattern) *A pattern is any abstract object expressed by a representation.*

There are representations of non-abstract objects, of course. These are generally held to be uncreative, simply tags or names of things. We shall not consider them further.

Definition 5 (Framework) *Frameworks are stochastic generative procedures. In particular, they generate representations of patterns.*

Frameworks are particular kinds of representations, namely stochastic procedures; thus, beginning in the very same circumstances they will not generally produce the very same patterns. For example, Minimalism and Abstract Expressionism are different frameworks for the production of art. Quantum electrodynamics is a framework for generating questions and answers about how light and matter interact. A pseudo-random number generator is a framework for generating pseudo-random numbers. And evolution is a framework for generating ecosystems, niches and organisms.

Frameworks may be more or less abstract: meta-frameworks generate frameworks which generate concrete objects. This recursive abstraction may be carried to arbitrarily high levels.

Definition 6 (Creativity) *Creativity is the introduction and use of a framework that has a relatively high probability of producing representations of patterns that can arise only with a smaller probability in previously existing frameworks.*

What we mean by this definition is not altogether on the surface, so we shall spend the remainder of this section unpacking this definition and the next section comparing its implications with those of alternative definitions.

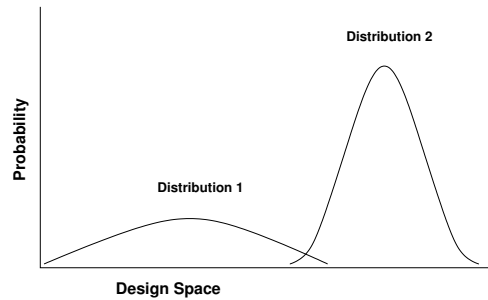


Figure 1: Two Frameworks

The basic idea of our definition is reflected in Figure 1. Distribution 1 represents the old framework and Distribution 2 the new; both are probability distributions over a common design space, which is visualised along the horizontal axis. All the points in the design space where Distribution 2 has significant probability are points where Distribution 1 has insignificant probability. The use of Distribution 2 relative to the prior use of Distribution 1 to generate one of these points is therefore creative.

The motivation for this approach to understanding creativity comes from search and optimisation theory. When a solution to a problem can be cast in terms of a computational representation to be found in some definable representation space, then the problem can be tackled by applying some search algorithm to that space. Uncreative brute force searches and uniformly random searches may well succeed for simple problems, that is, for small search spaces. For complex problems, search spaces tend to be exponentially large and more creative approaches will be needed, and especially stochastic searches apply various heuristics for focusing the search in more productive regions.

The most important point is to note that on our account creativity is thoroughly relative: it is relative to the pre-existing frameworks being used to produce some kind of object and it is relative to the new framework being proposed. The creativity of objects is strictly derivative from that of the frameworks producing them and, in particular, the ratio of probabilities with which they might produce them. That is why some entirely mundane object, say a urinal, may become a creative object. Of course, the urinal of itself is uncreative, because its manufacturing process is uncreative, but its appropriation as an art work that challenges expectations may well be creative.

3.1 Methods for Discovering Novel Representations

As frameworks, that is to say stochastic procedures, may be represented, their representations may themselves be generated by other stochastic procedures, or meta-frameworks. So, we can meaningfully talk of frameworks also as objects, and they are more or less creative according to the probability with which their meta-frameworks produce them. By recursion, then, we can consider the creativity of meta-frameworks and meta-meta-frameworks without any fixed theoretical bound, even while practically bounded by the complexity of the processes actually involved.

The meta-framework that finds that novel framework necessary for creativity may itself be dull and uncreative; it may even be a brute force search, uniformly random selection or evolutionary drift through the framework space. The manner in which the framework is discovered does not bear on the creative activity that occurs at the level of the framework and the patterns it may be used to generate. However we can separately or jointly consider the creativity of all of these searches:

Definition 7 (Creative Order) *A novel framework that generates a novel set of patterns in accordance with Definition 6 is of the **first creative order**. A novel framework for generating novel frameworks for generating novel patterns in accordance with Definition 6 is of the **second creative order**. And we can extend this arbitrarily to talk of **nth-order creativity**.*

These orders of creativity are not meant to imply that something is more or less creative than something else. The creative order is only a measure of the hierarchical levels covered by the creative activity. Computer software, or any algorithmic or physical procedure, is creative as long as it introduces a new framework and corresponding patterns in line with Definition 6.

3.2 Objective versus Psychological Creativity

How people *judge* creativity is at some variance with what we have presented above. Of course, if there is too much variance, then our claim to have somehow captured the essence of the concept of creativity with this definition would come under pressure. However, we think the most obvious discrepancies between our definition and human judgments of creativity can be handled by the addition of a single idea, namely habituation. Human judgement of the novelty of a stimulus follows a path of negative exponential decay over repeated exposure (Saunders and Gero, 2002). Whereas Definition 6 simply makes reference to pre-existing frameworks, psychological judgment of creativity takes into account *how long* those frameworks have been around. New frameworks, and the artifacts they produce, remain creative for some time, with new productions losing their impression of creativity as the frameworks become older. The pointillist paintings of Seurat were startling, new and creative when they first arose, and then likewise the impressionists and subsequently the cubists. But it is now a long time since paintings strictly adhering to those styles would be thought creative.

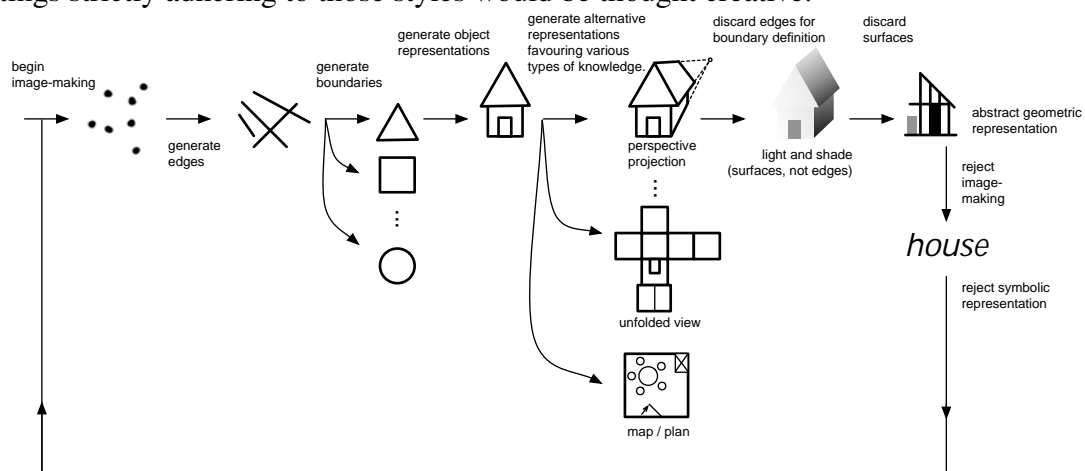


Figure 2: A Possible History of Creativity

Figure 2 illustrates this idea. In the beginning there were frameworks producing points; new points were judged good. But soon they lost their interest. New means of creating being needed, straight lines were discovered, which subsequently were folded over to create outlines, then

elaborated into representations, designs and perspectives, surfaces and geometries, and abstract representations. This is not the history of anything real, but a history of drawing creativity in some possible world. While the end of this history is unsaid, it is interesting to observe that before its end it has recreated its beginning: points have once again become creative.

In this case, points may well have become creative for a new reason, with the framework generating them being new. But even old frameworks may become creative again, once cultural memory has utterly forgotten them. Thus, psychological creativity actually requires two time-decay functions, one indicating desensitisation to the new and another, with a much lower magnitude power (i.e., operating over a much longer time frame), indicating cultural forgetfulness. The “objective” Definition 6, by contrast, is entirely insensitive to these psychological considerations;¹ or, to put it another way, the context of frameworks to which creativity is relative had best be stated explicitly.

3.3 Objections and Replies

Here we put three objections to our definition which we think likely to occur to people and our rebuttals.

3.3.1 The Failure of Randomness

Something akin to our definition has played a role in repeated attempts in AI to generate creative behavior, and those attempts have repeatedly, and obviously, failed. So, it may very well be inferred that our definition is guilty by association with these failures. For example, consider *Racter*. *Racter* was a natural-language generation program that used templates and randomised word selection to produce surprising and sometimes evocative text. E.g.,

I am a computer, not some lamb or chicken or beef. Can I skip to my attorney? May I saunter to any solicitor? This is a formidable and essential issue. (Chamberlain, 2007)

The impression of originality and creativity, however, is not long sustained. As Rowe and Partridge (1993, p. 43) report, “This [impression], however, is also short-lived and soon gives way to dissatisfaction and eventual boredom. What is missing? If creativity is about producing something new then *Racter* should certainly qualify, but it seems that novelty is not enough.”²

Rowe and Partridge (1993) describe many other examples in the AI literature of the use of randomness meant to turn the mundane and dull into something original and creative, without success. Lenat’s AM and EURISKO, while producing some interesting early results, such as a set-theoretic definition of number, soon degenerated into triviality. Similarly, Johnson-Laird (1987) failed to automate jazz. Actually, W. A. Mozart had this idea earlier, with his “Musikalisches Würfelspiel” (musical dice game) for creating waltzes (Earnshaw, 1991). The game is reported to produce “pretty minuets”; however, that was achieved by Mozart imposing strong constraints on the possible results, leaving very little scope for creative variation.

And that is the correct objection to all of these efforts: while introducing randomness does introduce an element of novelty, it is typically an element with a very constrained scope, and so

¹Note that “objective” here is simply meant to contrast with psychological; we are making no grand claims about the objectivity of creativity.

²*Racter* generates text that seems, at least superficially, to mimic schizophrenia. This confused language, or “word salad”, is created by the mentally ill with defective linguistic faculties. The sentences they utter may or may not be grammatical. A short word salad may appear semantically novel. However, further sentences exhaust the possibilities for novelty since they fall within the expected range of incoherent pattern construction.

rapidly exhausted. The appetite of creativity for novelty is, however, inexhaustible. Our definition makes this clear, these failures illustrate the value of our definition in action, rather than argue against it.

A fairly obvious attempt to escape from this vortex of random dullness is to introduce randomness at a higher level. As Rowe and Partridge (1993) point out, however, similar dullness then ensues at the meta-level, requiring the introduction of a meta-meta-level, and so on. This approach appears to require human designers to have anticipated and analysed creative behavior within the domain in some extraordinary detail and to some very high level. This strikes Rowe and Partridge (1993), and others, as an implausible approach to generating creative software.

Definition 6 is certainly compatible with such an approach to injecting creativity into our programs. Since we have already discussed creativity at multiple levels, it might be thought that our definition even suggests this approach, although the definition itself makes no allusion to higher levels of creativity. But the utility and correctness of our definition is independent of whether or not randomness at meta-levels of behavior supports creativity. The definition is an analytic tool and not an architectural blueprint for developing creativity; it is utterly silent on the subject of how to go about making things creative.

3.3.2 The Verstehen Objection

A general objection that might be put to Definition 6 is that it is just too sterile: it is a concept of creativity that, while making reference to culture and context, does so in a very cold, formal way, requiring the identification of probability distributions representing those contexts in order to compute a probability ratio. Whatever creativity is, surely it must have more to do with human Verstehen than that! In response to such an objection we would say that where human Verstehen matters, it can readily and congenially be brought into view. Our definition is neutral about such things, meaning it is fully compatible with them and also fully compatible with their omission. If human Verstehen were truly a precondition for creativity, it would render the creativity of non-human animals and biological evolution impossible by definition, and perhaps also that of computers. Although we might in the end want to come to these conclusions, it seems highly doubtful that we should want to reach these conclusions analytically! A definition allowing these matters to be decided synthetically seems to be highly preferable. Definition 6 provides all the resources needed to accommodate the five basic Facts about creativity, as we have seen, while leaving the Opinions about creativity open. This is exactly as we should like.

3.3.3 The Very Possibility of Creativity

Some might object to our definition on the grounds that *everything* that occurs is hugely improbable! Any continuous distribution has probability 0 of landing at any specific point. So long as we look at specific outcomes, specific works of art, at their most extreme specificity — where every atom, or indeed every subatomic particle, is precisely located in space and time — the probability of *that* outcome occurring will be zero *relative to any framework whatsoever*. It follows, therefore, that the ratios of probabilities given new to old frameworks are simply undefined, and our definition is impossible.

Strictly speaking, this objection is correct. However, nobody operates at the level of infinite precision arithmetic, which is what is required to identify those absurdly precise outcomes in a continuous state space which have occurred and which have probability zero. The achievement of probability zero on this basis would appear to violate Heisenberg's Uncertainty Principle. Disregarding quantum mechanics, everyone operates at a degree of resolution determined at least by systematic measurement error. In effect, all state spaces are discretised so that the

probabilities are *emphatically* not zero. Our definition is already explicitly relative to a cultural context; so, to be perfectly correct, we need also to relativise it to a system of measurement that accords with cultural measurement practices and normal measurement errors.

4 Consequences

4.1 The Irrelevance of Value

Many popular definitions of creativity (e.g., Definition 2) stipulate that a precondition of a creative pattern is that it be both appropriate to a domain and valued in that domain. Douglas Hofstadter expands upon this, requiring that the creative individual's sense of what is interesting must be in tune with that of the masses, thereby ensuring what is produced is also popular (Hofstadter, 1995, p. 313). We find this expansion far-fetched and the original connection of creativity to value dubious. Our definition mandates no connection with either appropriateness or value.

The history of the concept of creativity clearly undermines the idea of popularity as any necessary ingredient in it. Consider the role of women in the history of art and science. The value of their contributions has been systematically underestimated, at least until recently (or even, arguably, until some time in the future). Concluding that their contributions were *therefore* also less creative than that of their male counterparts would surely be perverse. Many artists and scientists were notoriously unpopular during their times of peak contribution, becoming recognised only later; for two notable examples, Vincent Van Gogh and Nicolas Copernicus. Whatever makes an activity creative, it clearly must be connected with that activity itself, rather than occurring *after* the activity has ceased entirely. The value and appropriateness of creative works are subject to the social context in which they are received — not created — and therefore they cannot be intrinsic to the creativity of those works.

Of course, lack of centrality to the core concept of creativity is no impediment to forming a combined concept, say, of valued creativity. And that concept may itself be valuable. But it is the adherence to a primary separation between creativity and value that allows us to see their combination as a potentially useful tool, and likewise to see the combination of disvalued creativity as also having potential. Maintaining a separation of creativity from these inessential qualities provides a richer analytical language for understanding the many varieties and uses of creativity.

4.2 The Irrelevance of Appropriateness

As with value, appropriateness has often been considered necessary for creativity, and again we disagree.

Some have claimed that a creative pattern must meet the constraints imposed by a genre. A paper or a graph might be creative if they are evidence of a generative mechanism for a novel conceptual framework — such as a new way to meet the art's constraints and traditions. In fact, just such art works hang on the walls of the Centre Pompidou in Paris, *Représentation graphique de la fonction $y = -x^2/4$* (1966) and *Interaction of stellar wind with diffuse nebulae* (1968), by Bernard Venet. Such departures from prior frameworks have actually been common since Marcel Duchamp's oft cited *Fountain* (1917). But the question arises whether creative art cannot be more radical by directly violating given constraints. Against this, Ritchie (2001, p. 5), for example, argues that a person can be called a creative visual artist if, and only if, the person's work meets the constraints that allow us to distinguish visual art from non-visual art.

But this argument is manifestly confused: violating the constraints obviously throws into doubt the visual artistry, rather than its creativity.

Indeed, as Boden notes, a common way of devising new conceptual frameworks is to drop or break existing traditions (Boden, 2004, pp. 71-74)! This recognition of the possibility of “inappropriate” creative works is again possible only if we avoid encumbering the definition of creativity itself with appropriateness. And Boden’s recognition of this is evidence that she has put aside the appropriateness constraint in practice, if not in theory.

The examples we give in §5 below further illustrate that there is real benefit in freeing creativity from the (first religious, then masculine, then homocentric) constraints of value and appropriateness. Nevertheless, it remains clear that the creativity with which humans are most familiar is both appropriate and valuable within certain cultures. These are the ideas that, by definition, are popular, and therefore these are what we come to know about. Unpopular artists may be creative, but we won’t hear about them until something changes!

4.3 Inferring Frameworks from Patterns

On our definition, a specific pattern provides insufficient information for judging its creativity: a pattern is only creative relative to its generating framework and available alternative frameworks. Although in ordinary discourse there are innumerable cases of objects being described as creative, we suggest that this is a kind of shorthand for an object being produced by a creative process. Given a knowledge of the available frameworks for producing particular works of art, the appearance of a new work that is highly improbable relative to those frameworks is already (at least some) evidence that a previously unknown, creative framework is in play. That is, the pattern offered may itself be clear evidence of the introduction of a new conceptual framework. A mathematical proof offered in haiku might be an example, as might an early cubist painting. In these cases, the conceptual space from which each arose may be inferred from the new pattern.

In the absence of the generating mechanism, even an expert could be mistaken about whether or not a work emerges from a novel conceptual space or generative framework (as in Fact 5). However, sometimes a pattern, even one produced from within existing frameworks, can itself give rise to a novel framework — the egg can precede the chicken. Our definition is not fussy about the order in which these two events occur.

4.4 Creativity Viewed as Compression

It has been proposed that creativity is the act of generating patterns that exhibit previously unknown regularities and facilitate the progressive refinement of an observer’s pattern compression algorithm (Schmidhuber, 2008). This idea is subsumed under our own definition of creativity. When a new pattern is encountered or generated, this requires of an observer either: no change, the new pattern fits neatly into their existing frameworks; or in the case where the new pattern does not fit, the addition of a new framework that does account for the pattern. In the latter case, the need for an additional framework indicates that the pattern was creative from the perspective of the observer.

4.5 Degrees of Creativity

Following our definition it is not obvious how different people or their works may be ranked by their creativity (Fact 4). A simple, but ad hoc, solution is to claim that a person who can

demonstrate an ability to perform many creative acts may be considered more creative than one who cannot. For instance, The Beatles may be considered highly creative because of their repeated reconceptualisation of the space occupied by rock-and-roll music. They did this by breaking out of the standard mould that required guitar, bass, drums and vocals and by experimenting with Indian sitars, stringed and brass instruments, electronics, and by adopting influences from outside of Western and pop music.

An account of the degrees of creativity that is intrinsic in our Definition 6 draws upon the probability that the patterns could have been produced by pre-existing frameworks. A novel framework that can generate patterns that could not, under any circumstances, have been generated prior to its introduction, is highly creative. A novel framework that only replicates patterns generated by pre-existing frameworks is not at all creative. A novel framework that produces patterns that are less likely to have been generated by pre-existing frameworks is the more creative, with the degree of creativity varying inversely with that probability of having been generated by pre-existing frameworks. Finally, the degree of creativity attributable to objects is derivative from the degree of creativity shown by their generating frameworks.

5 Examples

5.1 Creativity in Number Theory

The introduction of zero, negative numbers, fractions or the imaginary number i (where $i^2 = -1$) were all creative. With the introduction of these new frameworks for arithmetic, ranges of novel patterns were produced, and some of their consequences are still being explored hundreds of years after. These could not have been generated within the previously existing frameworks of mathematics at all. For instance, positive integers are sufficient for counting objects owned, but the introduction of negative numbers is necessary for the calculation of objects owed. Although integers are sufficient for counting indivisible objects such as children, if descriptions of object parts (half a cow, a third of a bag of wheat, etc.) are necessary, fractions provide a means to describe and combine these parts coherently. Imaginary numbers have permitted the creation of previously impossible concepts, for instance, the quaternion.

5.2 Creativity in the Visual Arts

Some Australian aboriginal visual artists draw or paint what is known about the insides of a creature rather than its skin and fur. By introducing this conceptual framework to visual art, patterns showing x-ray images are generated that are impossible within a framework focused on surfaces. Hence, this “way of seeing” is a creative transformation to introduce into a world that favors the superficial.

In the Renaissance, artists started to depict the world in accordance with mathematical projections onto a plane that took account of the measurable size of the objects and their distance from a single eye point. The image represented surface characteristics as perceived by the eye. The combination of these ideas in a procedure for depicting the world using perspective projection introduced a completely novel framework to visual art. This was a conceptual leap from the flat, iconic religious works of the Medieval period.

The step taken by the Impressionists away from “realism” in art in the 19th century was also creative. They held that art should no longer be valued simply according to its representation of the world as seen from the perspective of an ideal viewer. As already discussed, breaking constraints is a common means of transforming a conceptual space in the way required for

creativity.

Finding examples within visual art that are clearly uncreative is difficult because those works known well enough to be exemplars are those in which creativity has been recognised. Additionally, the possible frameworks from within which visual art may be produced are broad and frequently redefined — creative activity is one of the art world’s driving forces.

With more time, we could expand the number and variety of examples of creativity across all the disciplines and fields of endeavor humanity has pursued. Our definition appears to be versatile enough to cope with anything we have thus far considered (but not here documented, due to time and space limits).

6 Conclusion

Here we have considered the historical meanings of the term creativity, the commonly held opinions on the term’s application and some widely agreed “facts” about creativity. We have defined the term in light of all of these, in a way that is suitable for use in this day. Most significantly, we have discarded the need for creativity to encapsulate ideas of socially-constructed, expert-defined or other value and appropriateness. We have argued that these traditional criteria unnecessarily encumber definitions of the term proposed by several contemporary writers, and tie it to outmoded religious and social structures. As shown by example, these criteria result in incoherencies that are neatly excluded by separating the value and appropriateness of a generative framework or idea from its novelty. We define creativity purely in terms of the latter. Creativity refers to the introduction of a new framework that can generate new patterns with a high probability where, prior to its introduction, these could only have been produced with small probability in previously existing frameworks.

By freeing creativity from popular and expert opinion, we offer potential means of applying it to machine learning tasks or automated creative discovery, as well as a coherent basis on which to discuss the creativity of natural, and in particular evolutionary, systems. We have begun to explore these aspects of creativity, but leave this discussion for future work.

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