

CREATIVITY: HOW DOES IT WORK?

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1 Introduction

Creativity is the ability to come up with ideas that are new, surprising, and valuable (Boden 2004). I'm using "idea" as a shorthand, catch-all, term here. It can be a concept, a poetic image, a scientific theory, or even a particular form of taxation ... all of which are commonly called ideas. But it can also mean a style of painting or dancing, a way of building a bridge or skinning a cat, a millinery design, a cooking recipe, a recipe for home-made bombs ... or even a plan for delivering them to maximum effect.

As that long list suggests, creativity is found in every area of life: not just art, not just science, and not just business. Moreover, it's an aspect of normal adult human intelligence. So every one of us has it, although some of us display it more often, and more convincingly, than others.

By "more convincingly", I mean that some people repeatedly produce ideas that are regarded as highly valuable--and which, so far as is known, *no-one else has ever had before*. (They are "historically" creative, or H-creative.) Most people, by contrast, produce only moderately interesting ideas, many of which are already known by other people even though they are *new for the individual concerned*. (They are "psychologically", or "personally", creative: P-creative, for short.)

What different people regard as interesting varies, so new ideas can be valuable in many different ways. Encyclopedia writers, gallery curators, chemists, sculptors, property developers, entrepreneurs, and advertising executives... focus on different sorts of creative idea, different sorts of value. But for all these groups, it's H-creativity that they're most interested in.

However, if an idea is H-creative it must necessarily be P-creative too. So the first step to understanding H-creativity is to understand P-creativity. In other words, we need to ask how someone can come up with an idea that *they* have never had before. Some of those ideas will turn out to be H-creative as well, but the core processes--though not, of course, the details--of idea-generation are much the same in all cases.

Understanding how P-creativity works would be interesting in itself, as an exercise in psychology. But it would also be useful. For if we want to encourage creativity, in our school children and/or in the workforce, we had better have some idea of *just what sorts* of mental process are involved. We'll see, in Section D below, that different types of creativity can be fostered in different ways ... although all of them can be--and, sadly, too often are--*discouraged* in much the

same way.

Some people seem to be offended by questions about "how creativity works", believing that it's not possible for us to understand this. If they merely mean that we can't usually know, in every detail, how this or that novel idea (poetic image, symphony, mathematical proof ...) came about on a particular occasion, then they're right. Quite apart from anything else, we don't usually know enough about the contents of the individual creator's mind—even if that individual is *oneself*. But if they mean that we can't understand *the general principles* by which creative ideas arise, then they're mistaken.

Creativity doesn't work by magic--nor by divine inspiration, either. Nor can we explain it in terms of intuition. It's true, to be sure, that creativity involves intuition. But to say that doesn't tell us much, since the word "intuition" is just a placeholder for *some unknown psychological process, invisible even to the creative person him/herself*. If we want to understand how creativity is possible, how human minds can come up with ideas that are both new and valuable, we can't rely on appeals to intuition. Something more constructive needs to be said. In other words, we need to understand how "intuition" actually works.

Creativity isn't the only mental ability that depends on "invisible" (non-introspectible) processes. For instance, we're unaware of the processes that enable us, most of the time, to speak in perfectly grammatical sentences. But creativity seems especially mysterious. That's because its results, unlike grammatical sentences, are always surprising—and sometimes utterly amazing.

If one compares the surprise we experience in various cases of creativity, one will find that there are three different sorts of surprise. We may be surprised because a new idea is statistically unusual, contrary to commonsense expectations—like an outsider winning the Derby. Or we may be surprised because we hadn't realized that the new idea had been a possibility all along. (Compare discovering a beautiful village tucked away in a hollow between two spurs of the Motorway. Its location had always been marked on the map, but we hadn't examined the whole map closely.) Third, we may be surprised by something that we had previously thought impossible, and which we still see as utterly counterintuitive. (Here, think of the very first exhibition of Impressionist paintings, or imagine the impact on non-physicists of the introduction of wireless, or television.) In such cases, it seems as though a particular creative idea simply couldn't have arisen--and yet it did.

These three sorts of surprise correspond to three ways of coming up with new ideas, three different answers to our question "How does creativity work?" In other words, they point to three types of creativity--discussed in Section B, below.

There's another kind of surprise as well, focused not on the nature/likeness of the idea itself but rather on the fact that it's being offered to us as something

valuable.

As remarked above, values in many areas are disputable--and even highly changeable. Sometimes, they can change virtually overnight--due to commercial decisions in the fashion industry for instance (enticing the public to buy new clothes even though they aren't strictly needed), or to what some widely admired "celebrity" happened to wear to a high-profile party. At other times, the change may take years to happen. The first Impressionist paintings had to be shown in a special hall, because the official exhibition simply wouldn't accept them. But having been near-universally rejected at first, they can now be seen every day on birthday cards and chocolate-boxes. This gradual change from disgusted rejection to clichéd acceptance is a special case of the value-change that typically accompanies the third type of creativity discussed below.

There may, of course, be some universal or near-universal values, more resistant to cultural change. Two possible examples are symmetry and shininess. Quite apart from their cross-cultural popularity, there are good biological reasons why these two values have evolved (Boden 2006: 8.iv.c). And psychologists have identified other naturally evolved tendencies to favour perceptible features, and behave towards them in a particular way; certain shapes or textures, for instance, suggest opportunities for locomotion, feeding, holding, stroking, or courting. These near-universal values are prominent in craftworks, which is why the crafts are readily intelligible across cultures (Boden 2000). But even biologically-based values can be deliberately transgressed, and their opposites admired in their stead. Think of the highly asymmetrical architecture of Daniel Libeskind, for example.

In short, the surprise we feel on encountering a creative idea is sometimes due, in part, to the unfamiliar *values* that we're being invited to adopt. Mostly, however, it is due to the novelty of the idea in itself. We're surprised that it even happened, never mind whether it is obviously "valuable". And here, the three sorts of surprise listed above correspond to three different ways of coming up with new ideas, three different answers to the question "How does creativity work?"

2 The three types of creativity

The three types of creativity are *combinational*, *exploratory*, and *transformational* creativity (Boden 2004: chaps. 3-6). They're distinguished by the types of psychological process that are involved in generating the new idea.

The exercise and appreciation of each of these forms of creativity depends upon specific cultural knowledge. Someone from a different culture may not even be able to recognize the novelty involved, and *a fortiori* they may not be able to understand or value it. The "someone from a different culture" needn't be a foreigner: they may be your next-door neighbour, equipped with a range of

knowledge and cultural interests different from yours. If so, they'll have to undergo a learning process if they're ever to understand the novelty and to appreciate its value.

Combinational creativity involves the generation of unfamiliar (and interesting) combinations of familiar ideas. In general, it gives rise to the first type of surprise mentioned above. Just as one doesn't expect the outsider to win the Derby, because that doesn't normally happen (that is, it's statistically unusual), so one doesn't expect ideas X and Y to be combined. On the contrary, they're normally regarded as being mutually irrelevant.

Everyday examples of combinational creativity include visual collage (in advertisements and MTV videos, for instance); much poetic imagery; all types of analogy (verbal, visual, or musical); and the unexpected juxtapositions of ideas found in political cartoons in newspapers. Each of these can sometimes be both startlingly novel, and hugely appropriate--in other words, highly creative. Think of the most telling images in your favourite poetry, or of the last newspaper cartoon that made you laugh out loud on your train journey. In either case, the two (or more) ideas that are conjoined aren't obviously relevant to each other--hence part of your surprise. Yet, on further consideration, you can see that they allow an interpretation wherein they're closely, perhaps very closely, linked--hence the other, and especially satisfying, part of your surprise.

Many attempts to define creativity, even within the specialist psychological literature, confine it to this first type alone. Forming unfamiliar combinations, we're told, is the only creative game in town.

But that's a mistake, for exploratory and transformational creativity are different. They're both grounded in some previously existing, and culturally accepted, structured style of thinking--what one can call a "conceptual space." Of course, combinational creativity depends on a shared conceptual base--but this is, potentially, the entire range of concepts and world-knowledge in someone's mind. A conceptual space is both more limited and more tightly structured. It may be a board-game, for example (chess or Go, perhaps), or a particular type of music or painting, or a specific way of visualizing the structure of molecules in chemistry.

In exploratory creativity, the existing stylistic rules or conventions are used to generate novel structures (ideas), whose possibility may or may not have been realised before the exploration took place. To continue the analogy mentioned in Section A, you may or may not have had some reasons to expect to find an unknown village nestling between the Motorways. The vast majority of creative work in the arts and sciences is of this kind (in the latter case, it is what philosophers of science call "normal" science: Kuhn 1962).

Exploratory creativity is not to be sneezed at. There are three reasons for this.

First, most artists and scientists spend their working time engaged in exploratory creativity. Only very few go beyond it, and they do so only occasionally.

Second, exploratory creativity can produce highly valued (beautiful, useful, interesting...) structures, or ideas. You are already familiar with nineteenth-century Impressionism, I assume. But if you were to enter a room full of previously-unseen Impressionist canvasses, only a mind-numbing glut of chocolate-boxes would lead you to say "Oh no! Not more Monets!"

And third, it can often offer surprises that are rather deeper than merely seeing the previously unseen. For exploratory creativity need not be a matter of adopting the current style unthinkingly. It can also involve the deliberate search for, and testing of, the specific stylistic limits concerned. To do that is to discover just which types of structure can be generated within this space, and which cannot. If you've ever visited a retrospective exhibition of a painter's lifework, where the canvasses are arranged chronologically, you will have seen this process going on before your eyes. (Had it not gone on at all, there would be little interest in showing the years-long collection of work: only a dotting family-member, with more money than sense, would have arranged such an exhibition.)

In testing the potential and limits of the adopted style, exploratory creativity sometimes involves varying it too. Some of the rules, conventions, or constraints that define the style can be slightly altered, or "tweaked" (again, this is readily visible in a retrospective exhibition). In that case, the new ideas that arise wouldn't--couldn't--have arisen without the tweaking. Nevertheless, they will clearly be "of a piece with" (in the same *general* style as) the earlier, more familiar, examples. As such, they will be readily intelligible, in terms of the methods of interpretation already in place to understand the style. They may cause an extra frisson of excitement, but no amazement--and certainly no bewildered incomprehension.

Amazement, bewilderment, and incomprehension are caused rather by transformational creativity. For it is this which leads to "impossibilist" surprise. The reason is that some deep dimension of the thinking style, or conceptual space, is altered--so that structures can now be generated which *could not* be generated before, and which are *not* "all of a piece" with the previous style. Imagine altering the rule of chess which says that pawns can't jump over other pieces: they're now allowed to do this, as knights always were. The result would be that some games could now be played which were literally *impossible* before. Similarly, to start painting abstract pictures, where previously the paintings had all been representational, is to invite incomprehension as well as to cause surprise. The greater the alteration, and the more fundamental the stylistic dimension concerned, the greater the shock of impossibilist surprise.

The distinction between "tweaking" and "transforming", and therefore between exploratory and transformational creativity, is a matter of degree. Afterall, I said

above that the novel ideas occurring after the exploratory tweaking "couldn't have arisen" before. However, in exploratory creativity the variation in style is relatively minor, and relatively superficial. That's why the result is readily intelligible, even though it is a novel *variation* as well as a novel *structure*. It's also why the result is immediately accepted as valuable, not rejected as disturbing--still less, as absurd.

Transformational creativity is different, for here the variation is greater, and the stylistic dimension that is being varied is deeper. The resulting change is so marked that the new idea may be difficult to accept, or even to understand. Sometimes, many years will have to pass before it can be valued by anyone outside a small group of aficionados. Picasso's pioneering cubist canvas of *Les Femmes d'Alger (O. J. R. Version O)*, for instance, was initially spurned even by his close circle of fellow-artists. He kept it hidden in his studio for several years before exhibiting it.

Even in transformational creativity, not every dimension of the style will have been changed. So there will be both structural continuities and structural discontinuities between the untransformed space and its seemingly impossible successor. The nature of these continuities and discontinuities will affect the valuation of the new idea. Consider our example of the transformed chess-game, for instance. If some feature of the game, which you had enjoyed before the change, is retained then you'll find something to enjoy in the transformed version. You may, however, be so averse to jumping pawns--perhaps they make you feel giddy?--that you decide to revert to old-style chess nevertheless.

The transformationally creative thinker may add new rules, as well as dropping/varying old ones. And he/she may then engage on a lengthy process of *exploring* the new style more fully. One clear example concerns the composer Arnold Schoenberg (Rosen 1976). He transformed the space of Western tonal music by dropping the fundamental home-key constraint: it was no longer the case that every composition must favour one of a finite number of sets of seven notes (the major and minor scales). Atonality was born. But besides dropping this constraint, Schoenberg experimented by adding new ones. At one point, for instance, he said that each composition should contain *every* note of the chromatic scale. Musical exploration could then ensue on this basis. But the more radical transformation was the decision to drop the constraint of a home key.

In general, transformational creativity is valued more highly than the other two types. (That's less true of literature than of the other arts, because language offers scope for especially rich creative combinations, and because the theme of human motivation offers huge exploratory potential.) However, novel transformations are relatively rare. The artists and scientists whose names are recorded in the history books are usually remembered above all for changing the accepted style. (Again, that's somewhat less true of writers.)

The three types of creativity are analytically distinct, in that they involve different types of psychological process for generating P-novel ideas. But these processes sometimes occur together. For instance, an advertising graphic may *both* explore a recognizable visual style (specific to the brand concerned) *and* combine two or more images that are normally kept apart. That's partly why it's usually more sensible to ask whether this or that *aspect* of an artwork or scientific theory is creative, and in what way, rather than asking "Is this new idea creative: yes or no?"

3 Creativity in Computers??

If we could say "just which" psychological processes underlie creativity, we should be able to model them in computers. And indeed, over the last twenty years an increasing amount of work has been done in this area (Boden 2004: chaps. 6-8. 12; Boden 2006: 13.iv).

I'm not referring to computer art, which began in the late 1950s and has burgeoned since then. For computer art (with a few exceptions) is done only with the aim of producing something visually/musically interesting, not with the aim of understanding how human artists' minds work. Modeling creative processes as such is a different enterprise.

All three types of creativity have been modeled in this way. The most successful examples concern exploratory creativity. This requires, of course, that the programmer, or a close collaborator, knows enough about the domain concerned (maths, chemistry, graphics, music...) to be able to identify the constraints that define the style being investigated. For example, only someone very familiar with Bach fugues, and preferably with what musicologists have written about them, could write a plausible fugue-generating program.

Many people believe that *no* program could possibly generate "plausible" Bach fugues, or Chopin Nocturnes, or.... They're wrong. The composer David Cope wrote a program in the 1980s which could produce very convincing pastiches of a wide range of famous composers. Indeed, it's not clear that "pastiche" is always the right word. For when these pieces are played by human musicians in the concert hall, they often "fool" even the best musical experts (Cope 2006). Similarly, an architectural program based on Frank Lloyd Wright's *Prairie House* style has come up with every one of the 40-odd houses he designed himself, plus others--clearly within the same general style--which no-one, Lloyd Wright included, has ever seen before (Koning and Eisenberg 1981).

One can certainly say that these house-designs and musical compositions are *new*. That is, they are newly-discovered structures within the space of possibilities defined by the style concerned. Moreover, they're valuable: after all, exploratory creativity in general is grounded in some already accepted (valued)

style. But *the style itself* isn't new. In other programs model exploratory, not transformational, creativity. Whether a computer could ever come up with a new style is a hotly disputed question.

It's not obvious that it couldn't, because some programs are able to alter their own rules in unpredictable ways, so that they can generate structures on Tuesday which they couldn't have generated on Monday. These are the so-called evolutionary programs, which contain mechanisms ("genetic algorithms") that can make random changes in the program's rules and select the most promising for further "breeding". Sometimes, the selection is done at each generation by a human being. But sometimes, the programmer chooses a list of criteria (the "fitness function") by means of which the program itself selects the winners automatically.

There are three problems with these self-transforming programs, however. First, if the "mutations" allowed are so radical that a seemingly new type of structure does result then it may be so different from what went before that the human beings using the program see it as having little or no value. Second, radical transformations won't lead to a sustained new *style* (unless the transformed program is immediately "frozen" by the programmer), because another, very different, radical change may happen within a few generations. And third, some people argue that genuine novelty isn't available even from evolutionary programs, because every structure generated by the computer must lie within the possibility-space defined by the program itself. (If the program is allowed to interact with the physical world, however, a genuine novelty may arise: for instance, a new--not merely an improved--type of sensor: Bird and Layzell 2002.)

One might think that there would be no problem modeling combinational creativity on a computer. After all, a computer program could come up with novel combinations of ideas until kingdom come. It could even do this by using mechanisms broadly comparable to associative memory in human beings (Boden 2004: chap. 6). Here, however, the problem--again--is the assignment of value. Most of the associations produced by the program will have little or no interest for human users. Conceivably, someone looking for novel ideas for an advertising campaign might find it worthwhile to sift through the novel associations generated by a computer--but they'd probably be far better off relying on their own powers of association and world-knowledge. (For an example of computerized combinational creativity, used for generating simple jokes, see Binsted and Ritchie 1997.)

Computer models of creativity can help us to think clearly about how creativity works. That's true even in the cases where their performance is disappointing, for then we can ask *just why* they failed to come up with the expected results. And we've seen that they can sometimes give results that match human creativity, especially of the exploratory type.

Whether even those examples are "really" creative, however, is a very different question: philosophical, not scientific. Maybe only the programmers are truly creative, and any seeming "creativity" in the computer should be attributed instead to them? That—very common—opinion is often based on one or more of four highly controversial philosophical assumptions (about consciousness, brain-stuff, and meaning, for example—Boden 2004: 286-300). We can't go into them here ... but notice that, being "highly controversial", they can't be taken for granted.

There's a fifth reason for people's denying that computers can be creative, which is that they doubt whether even human creativity can be scientifically understood. If the argument of the previous sections is correct, however, they're mistaken.

4 How Creativity Can be Encouraged

If we want to know how creativity can be *discouraged*, the answer is simple. Since all types of creativity involve novelty and surprise, any cultural attitudes that punish people for providing these will thereby hinder their creativity.

Suppose that someone—whether a schoolchild or an adult—comes up with an unexpected (i.e. surprising) answer to a question. If their answer is immediately dismissed as a "mistake", or—still worse—if the individual is scorned as "stupid", they will be much less likely to offer new answers (or perhaps *any* answers) in the future. Of course, people do sometimes make mistakes. But there are ways of conveying this without also implying that the person is stupid. Indeed, there are often ways of conveying it in a constructive fashion, so that the person can see how their (mistaken) idea could have been on the right lines if the question/problem had been slightly different.

The more one hopes for truly surprising ideas, the more important it is not to undermine people's self-confidence. For the evidence suggests that what makes for an especially H creative person is *not* their having any special idea-generating mechanisms in their heads. Rather, it is their motivation, self-confidence, and single-minded commitment to the domain in question (Perkins 1981; Boden 2004: ch. 10). Indeed, high-profile H-creators are often monsters of egotism and selfishness (Gardner 1993). In the case of transformational creativity in particular, this makes sense. For transformational creativity (by definition) breaks the commonly-accepted rules, and challenges other people to adopt new values in accepting the novel idea. It is therefore likely to meet with incomprehension, bewilderment, and even scorn. The H-creator needs plenty of self-belief to weather such storms.

Turning to the happier topic of how to *encourage* creativity, the answer isn't quite so simple. For here, we must distinguish carefully between the three types. The sort of experience or training that is best suited to fostering one type will differ from that best suited to fostering another.

Combinational creativity, as we've seen, depends on two things: making unfamiliar combinations of familiar ideas, and doing so aptly, or appropriately. Several forms of encouragement are relevant here.

The first is to enlarge the variety of concepts in the person's mind. Someone who doesn't possess a host of concepts, drawn from a wide range of domains, will be very unlikely to come up with startling new combinations. So an essential part of helping someone to be creative in this particular way is to widen their general knowledge, encouraging them to engage in many different interests and activities, and perhaps also to draw on more than one culture.

However, there's no guarantee that a well-stocked mind will generate large numbers of novel associations. In addition, then, one should foster a habit of experimenting with unfamiliar conceptual "mixtures". For example, a child (or adult) could be given two or more ideas drawn--possibly at random--from different areas, and asked to make up a story, or compose a sentence, in which all those ideas feature. Or again, one could encourage the person to ask "What does that remind you of?", in the expectation that at least a dozen things will come to mind. In this sort of way, the various exercises recommended in the many self-help books on creativity (e.g. Buzan 2004; De Bono 1982, 2000) can induce people to think more adventurously than they normally do.

Finally (the most difficult of all), one should help the person to learn how to judge the results, so as to pick out the more interesting combinations. This may involve making explicit comparisons and contrasts between the newly-joined ideas. And it can be helped by giving the person experience of existing examples of combinational creativity, and asking them just what is "interesting" about the different cases. Careful consideration of the imagery in poems, for instance, can awaken the reader to conceptual connections that they hadn't consciously realized before. Again, self-help books on creativity usually provide helpful hints on how to assess novel mixes of ideas.

As for exploratory creativity, mere general knowledge and richness of associations won't be enough. The person will also need prolonged experience of, and perhaps special training in, the thinking style concerned.

If that style is interestingly complex, and/or if it requires special skills (such as mixing oil- paints, playing a keyboard, or synthesizing chemical molecules), it may take years to become competent in it, so that one can produce new structures satisfying the stylistic constraints in question. Learning how to test and tweak the style will take even longer. (Renowned composers, even including child-prodigies such as Mozart, seem to need about twelve years of total immersion in music before they can write something that is "creative" rather than merely competent; on the other hand, even "ordinary" people, if given enough training, can reach unusual heights in musical creativity: Kunkel 1985.)

It follows that exploratory creativity is *not* primarily an exercise in “free thinking”. Indeed, even combinational creativity isn’t wholly unconstrained, since the novel association (which may have been--though usually isn’t--produced by random processes) must be evaluated for aptness. In other words, the belief that one can best equip children (or adults) for creativity by encouraging them to ignore all conceptual constraints and think only “for themselves”, is mistaken. As that term “constraints” suggests, creativity involves personal discipline as well as freedom. Where exploratory creativity is in question, that discipline may require years of painstaking practice. Ultimately, to be sure, the style may become so familiar that the person can explore it effortlessly. But a great deal of effort will have been needed to learn it in the first place.

Transformational creativity, as we’ve seen, is built on the exploratory variety. For here, the style is not merely tested and tweaked, but to some extent transcended. That’s done by altering, adding, or deleting dimensions of the original conceptual space--which implies that those dimensions must already have been learnt by the person concerned.

Some forms of alteration will apply only to a specific dimension of a specific conceptual space. For instance, we saw in Section B that Schoenberg altered tonality partly by insisting on using every note of the chromatic scale. Others are more general: these include the negation of an existing dimension, or its deletion, or its iteration. For instance, in discovering the structure of benzene, the chemist Friedrich von Kekule transformed his idea of a chemical molecule from an open string to its opposite, a closed string (Boden 2004: 25-8, 62-71). And Schoenberg dropped the seven-note scales that defined tonal music.

One way of encouraging transformational creativity is to present the person with many such examples, asking them to consider just what dimension/s has/have been changed, and how. Once they understand the nature of transformational creativity they will be in a better position to experiment with it. As always, however, they will also need to be able to evaluate their own novel ideas. This form of creativity is especially likely to be resisted. And perhaps rightly so: not all transformations are valuable. Whereas mere exploratory tweaking is unlikely to *destroy* the interest of the novel idea (although it may lessen it), a radical transformation can do so.

It would be helpful, too, if the “transformational” creator could be encouraged to present their ideas in ways that will help other people to understand, and to accept, them. Understanding requires a realization of the similarities between the new style and the previous one, and a sensitive explanation on the part of the originator should be able to provide this. Acceptance is even more elusive, and may require additional persuasion on the part of the creator ... for which there can be no set formula.

And here we come full circle, for the self-confidence that’s needed to persevere--

and perhaps eventually to persuade--in transformational creativity is the greatest of all. Whichever form of originality we're trying to encourage, however, the person's motivation must be fostered as well as their "brainpower".

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