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The Social Impact of Self-Regulated Creativity on the Evolution of Simple versus Complex Creative Ideas

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Abstract

Since creative individuals invest in unproven ideas at the expense of propagating proven ones, excess creativity can be detrimental to society; moreover, some individuals benefit from creativity without being creative themselves by copying creators. This paper builds on previous studies of how societies evolve faster by tempering the novelty-generating effects of creativity with the novelty-preserving effects of imitation. It was hypothesized that (1) this balance can be achieved through self-regulation (SR) of creativity, by varying how creative one is according to the value of one' creative outputs, and (2) that the social benefit of SR is affected by the openness of the space of possible ideas. These hypotheses were tested using EVOC, an agent-based model of cultural evolution in which each agent self-regulated its invention-to-imitation ratio as a function of the fitness of its inventions. We compared SR to non-SR societies, and compared societies in which the space of possible ideas was open-ended because agents could chain simple ideas into complex ones, to societies without chaining, for which the space of possible ideas was fixed. Agents in SR societies gradually segregated into creators and imitators, and changes in diversity were rapider and more pronounced than non-SR. The mean fitness of ideas was higher in SR than non-SR societies, but this difference was temporary without chaining whereas it was permanent with chaining. We discuss limitations of the model and possible social implications of the results.

Keywords: Agent-based model; creativity; imitation; individual differences; self regulation; cultural evolution EVOC.

Introduction

It is commonly assumed that creativity is desirable, and the more creative one is, the better. Our capacity for self-expression, problem solving, and making aesthetically pleasing artifacts, all stem from our creative abilities. However, individuals often claim that their creativity is stifled by social norms, policies, and institutions. Moreover, our educational systems do not appear to prioritize the cultivation of creativity, and in some ways discourage it.

Perhaps there is an adaptive value to these seemingly mixed messages that society sends about the social desirability of creativity. Perhaps what is best for society is that individuals vary widely with respect to how creative they are, so as to ensure that the society as a whole both generates novel variants, and preserves the best of them. This paper provides a computational test of the following hypotheses. The first hypothesis is that society as a whole benefits when individuals can vary how creative they are in response to the perceived effectiveness of their ideas. In theory, if effective creators create more, and ineffective creators create less, the ideas held by society should collectively evolve faster. The second hypothesis is that the space of possible ideas has to be open-ended in order to benefit from this self-regulation mechanism. In theory, the effectiveness of such a self-regulation should vary with the extent to which some ideas are fitter or more effective than others.

Definition and Key Features of Creativity

There are a plethora of definitions of creativity in the literature; nevertheless, it is commonly accepted that a core characteristic of creativity is the production of an idea or product that meets two criteria: originality or *novelty*, and appropriateness, adaptiveness, or *usefulness, i.e.,* relevance to the task at hand (Guilford 1950; Moran 2011). Not only are humans individually creative, but we build on each other's ideas such that over centuries, art, science, and technology, as well as customs and folk knowledge, can be said to evolve. This cumulative building of new innovations on existing products is sometimes referred to as the ratchet effect (Tomasello, Kruger, and Ratner 1993). Creativity has long been associated with personal fulfillment (May 1975; Rogers 1959), self-actualization (Maslow 1959), and maintaining a competitive edge in the marketplace. Thus it is often assumed that more creativity is necessarily better.

However, there are significant drawbacks to creativity

(Cropley et al. 2010; Ludwig 1995). Generating creative ideas is difficult and time consuming, and a creative solution to one problem often generates other problems, or has unexpected negative side effects that may only become apparent after much effort has been invested. Creativity is correlated with rule bending, law breaking, and social unrest (Sternberg and Lubart 1995; Sulloway 1996), aggression (Tacher and Readdick 2006), group conflict (Troyer and Youngreen 2009), and dishonesty (Gino and Ariely 2012). Creative individuals are more likely to be viewed as aloof, arrogant, competitive, hostile, independent, introverted, lacking in warmth, nonconformist, norm doubting, unconscientious, unfriendly (Batey and Furnham 2006; Qian, Plucker, and Shen 2010; Treffinger et al. 2002). They tend to be more emotionally unstable, and more prone to affective disorders such as depression and bipolar disorder, and have a higher incidence of schizophrenic tendencies, than other segments of the population (Andreason 1987; Eysenck 1993; Flaherty 2005). They are also more prone to drug and alcohol abuse, as well as suicide (Jamison 1993; Goodwin 1998; Rothenberg 1990; Kaufman 2003). This suggests that there is a cost to creativity, both to the individual and to society.

Balancing Novelty with Continuity

Given the correlation between creativity and personality traits that are potentially socially disruptive, it is perhaps fortunate that in a group of interacting individuals, not all of them need be particularly creative for the benefits of creativity to be felt throughout the group. The rest can reap the rewards of the creator's ideas by copying them, buying from them, or simply admiring them. Few of us know how to build a computer, or write a symphony, but they are nonetheless ours to use and enjoy. Of course, if everyone relied on the strategy of imitating others rather than coming up with their own ideas, the generation of cultural novelty would grind to a halt. On the other hand, if everyone were as creative as the most creative amongst us, the frequency of the above-mentioned antisocial tendencies of creative people might be sufficiently high to interfere with cultural stability; *i.e.,* the perpetuation of cultural continuity. It is well known in theoretical biology that both novelty and continuity are essential for evolution, that is, for cumulative, open-ended, adaptive change over time.

This need for both novelty and continuity was demonstrated in an agent-based model of cultural evolution (Gabora 1995). Novelty was injected into the artificial society through the invention of new actions, and continuity was preserved through the imitation of existing actions. When agents never invented, there was nothing to imitate, and there was no cultural evolution at all. If the ratio of invention to imitation was even marginally greater than 0, not only was cumulative cultural evolution possible, but eventually all agents converged on optimal cultural outputs. When all agents always invented and never imitated, the mean fitness of cultural outputs was also sub-optimal because fit ideas were not dispersing through society. The society as a whole performed optimally when the ratio of creating to imitating was approximately 2:1. Although results obtained with a simple computer model may have little bearing on complex human societies, the finding that extremely high levels of creativity can be detrimental to the society suggests that there may be an adaptive value to society's ambivalent attitude toward creativity.

This suggested that society as a whole might benefit from a distinction between the conventional workforce and what has been called a "creative class" (Florida 2002) This was investigated in the model by introducing two types of agents: imitators, that only obtained new actions by imitating neighbors, and creators, that obtained new actions either by inventing or imitating (Gabora and Firouzi 2012). It was possible to vary the probability that creators create versus imitate; thus, whereas a given agent was either a creator or an imitator throughout the entire run, the proportion of creators innovating or imitating in a given iteration fluctuated stochastically. The mean fitness of ideas across the artificial society was highest when not all agents were creators. Specifically, there was a tradeoff between C, the proportion of creators to imitators in the society, and p, how creative the creators were). This provided further support for the hypothesis that society as a whole functions optimally when creativity is tempered with continuity.

We then hypothesized that society as a whole might perform even better if individuals are able to adjust how creative they are over time in accordance with their perceived creative success. For example, this could result from mechanisms such as selective ostracization of deviant behaviour unless accompanied by the generation of valuable novelty, and encouragement or even adulation of those whose creations are successful. In this way society might self-organize into a balanced mix of novelty generating creators and continuity perpetuating imitators, both of which are necessary for cumulative cultural evolution. A first step in investigating this hypothesis was to determine whether it is algorithmically possible to increase the mean fitness of ideas in a society by enabling them to self-regulate how creative they are, and investigate the conditions under which this is possible.

The Computational Model

We investigated this using an agent-based model of cultural evolution referred to as "EVOlution of Culture", abbreviated EVOC (Gabora 2008)[1]. It uses neural network based agents that (1) invent new ideas, (2) imitate actions implemented by neighbors, (3) evaluate ideas, and (4) implement successful ideas as actions. EVOC is an elaboration of Meme and Variations, or MAV (Gabora 1995), the earliest computer program to model culture as an evolutionary process in its own right, as opposed to modeling the interplay of cultural and biological evolution[2]. The goal behind MAV, and also behind EVOC, was to distil the underlying logic of cultural

[1]The code is freely available; to gain access please contact the first author by email at liane.gabora@ubc.ca.

[2]The approach can thus be contrasted with computer models of how individual learning affects biological evolution (Best 1999; Higgs 1992; Hinton and Nowlan 1992; Hutchins and Hazelhurst 1991).

evolution, *i.e.,* the process by which ideas adapt and build on one another in the minds of interacting individuals. Agents do not evolve in a biological sense, as they neither die nor have offspring, but do in a cultural sense, by generating and sharing ideas for actions. In cultural evolution, the generation of novelty takes place through invention . EVOC was originally developed to compare and contrast the processes of biological and cultural evolution, but has subsequently been used to address such questions as how does the presence of leaders or barriers to the diffusion of ideas affect cultural evolution.

We now summarize the architecture of EVOC in sufficient detail to explain our results; for further details we refer the reader to previous publications (Gabora 2008; Leijnen and Gabora 2009).

Agents

Agents consist of (1) a neural network, which encodes ideas for actions and detects trends in what constitutes a fit action, (2) a 'perceptual system', which observes and evaluates neighbours' actions, and (3) a body, consisting of six body parts which implement actions.

The neural network is composed of six input nodes and six corresponding output nodes that represent concepts of body parts (LEFT ARM, RIGHT ARM, LEFT LEG, RIGHT LEG, HEAD, and HIPS), and seven hidden nodes that represent more abstract concepts (LEFT, RIGHT, ARM, LEG, SYMMETRY, OPPOSITE, and MOVEMENT). Input nodes and output nodes are connected to hidden nodes of which they are instances (*e.g.,* RIGHT ARM is connected to RIGHT.) Each body part can occupy one of three possible positions: a neutral or default position, and two other positions, which are referred to as active positions. Activation of any input node activates the MOVEMENT hidden node. Same-direction activation of symmetrical input nodes (*e.g.,* positive activation – which represents upward motion – of both arms) activates the SYMMETRY node. The entire reason for the neural network is to enable agents to learn trends over time concerning what general types of actions tend to be valuable, and use this learning to invent new actions more effectively. Without the neural network agents invent at random and the fitness of their inventions increases much more slowly (Gabora, 2008).

Invention

An idea for a new action is a pattern consisting of six elements that dictate the placement of the six body parts. Agents generate new actions by modifying their initial action or an action that has been invented previously or acquired through imitation. During invention, the pattern of activation on the output nodes is fed back to the input nodes, and invention is biased according to the activations of the SYMMETRY and MOVEMENT hidden nodes. We emphasize that were this not the case there would be no benefit to using a neural network. To invent a new idea, for each node of the idea currently represented on the input layer of the neural network, the agent makes a probabilistic decision as to whether the position of that body part will change, and if it does, the direction of change is stochastically biased according to the learning rate. If the new idea has a higher fitness than the currently implemented idea, the agent learns and implements the action specified by that idea. When "chaining" is turned on, an agent can keep adding new sub-actions and thereby execute a multi-step action, so long as the most recently-added sub-action is both an optimal sub-action and different from the previous sub-action of that action (Gabora, Chia, and Firouzi 2013).

Imitation

The process of finding a neighbour to imitate works through a form of lazy (non-greedy) search. The imitating agent randomly scans its neighbours, and adopts the first action that is fitter than the action it is currently implementing. If it does not find a neighbour that is executing a fitter action than its own current action, it continues to execute the current action.

Evaluation: The Fitness Function

Following (Holland 1975), we refer to the success of an action in the artificial world as its *fitness*, with the caveat that unlike its usage in biology, here the term is unrelated to number of offspring (or ideas derived from a given idea). The fitness function used in these experiments rewards activity of all body parts except for the head, symmetrical limb movement, and positive limb movement. Fitness of a single-step action F_n is determined as per Eq. 1. Total body movement, m, is calculated by adding the number of active body parts, *i.e.,* body parts not in the neutral position.

$$F_n = m + 5(s_a + s_t) + 2(p_a + p_t) + 10 * a_h + 2 * a_p \quad (1)$$

$s_a = 1$ if arms move symmetrically; 0 otherwise
$s_t = 1$ if legs move symmetrically; 0 otherwise
$p_a = 1$ if both arms move upwards; 0 otherwise
$p_t = 1$ if both legs move upwards; 0 otherwise
$a_h = 1$ if head is stationary; 0 otherwise
$a_p =$number of body parts moving upwards;

Note that there are multiple optima. (For example an action can be optimal if either both arms move up or if both arms move down.) The fitness F_c of a multi-step action with n chained single-step actions (each with fitness F_n) is calculated by Eq. 2.

$$F_c = \sum_{k=1}^{n} \frac{F_n}{1.2^{n-1}} \quad (2)$$

Learning

Invention makes use of the ability to detect, learn, and respond adaptively to trends. Since no action acquired through imitation or invention is implemented unless it is fitter than the current action, new actions provide valuable information about what constitutes an effective idea. Knowledge acquired through the evaluation of actions is translated into educated guesses about what constitutes a successful action by updating the learning rate. For example, an agent may learn that more overall movement tends to be either beneficial (as with the fitness function used here) or detrimental, or that symmetrical movement tends to be either beneficial (as with the fitness function used here) or detrimental, and bias the generation of new actions accordingly.

The Artificial World

These experiments used a default artificial world: a toroidal lattice with 1024 cells each occupied by a single, stationary agent, and a von Neumann neighborhood structure. Creators and imitators were randomly dispersed.

A Typical Run

Fitness and diversity of actions are initially low because all agents are initially immobile, implementing the same action, with all body parts in the neutral position. Soon some agent invents an action that has a higher fitness than immobility, and this action gets imitated, so fitness increases. Fitness increases further as other ideas get invented, assessed, implemented as actions, and spread through imitation. The diversity of actions increases as agents explore the space of possible actions, and then decreases as agents hone in on the fittest actions. Thus, over successive rounds of invention and imitation, the agents' actions improve. EVOC thereby models how "descent with modification" occurs in a purely cultural context.

Method

To test the hypothesis that the mean fitness of cultural outputs across society increases faster with social regulation (SR) than without it, we increased the relative frequency of invention for agents that generated superior ideas, and decreased it for agents that generated inferior ideas. To implement this the computer code was modified as follows. Each iteration, for each agent, the fitness of its current action relative to the mean fitness of actions for all agents at the previous iteration was assessed. Thus we obtained the relative fitness (RF) of its cultural output. The agent's personal probability of creating, $p(C)$, was a function of RF. It was calculated as follows:

$$p(C)_n = \begin{cases} 1, & \text{if } p(C)_{n-1} \times RF_{n-1} > 1 \\ p(C)_{n-1} \times RF_{n-1}, & \text{otherwise} \end{cases} \qquad (3)$$

The probability of imitating, $p(I)$, was 1 - $p(C)$. Thus when SR was on, if relative fitness was high, the agent invented more, and if it was low the agent imitated more. $p(C)$ was initialized at 0.5 for both SR and non-SR societies. We compared runs with SR to runs without it, both with and without the capacity to chain simple ideas into more complex ones.

Results

All data are averages across 250 runs. We first present the results of experiments in which chaining was turned off and thus only simple inventions were possible. Second we present the results of experiments with chaining turned on such that simple ideas could be combined into increasingly complex inventions.

The Effect of Social Regulation with No Chaining

With chaining turned off, the mean fitness of the cultural outputs of societies with SR (the ability to self-regulate inventiveness as a function of inventive success) was higher than that of societies without SR, as shown in Figure 1. However, the difference between SR and non-SR societies is only temporary; it lasts for the duration that the space of possible ideas in being explored. In both SR and non-SR societies mean fitness of actions plateaued when all agents converged on optimally fit ideas. Thus the value of segregating into creators and imitators is short-lived.

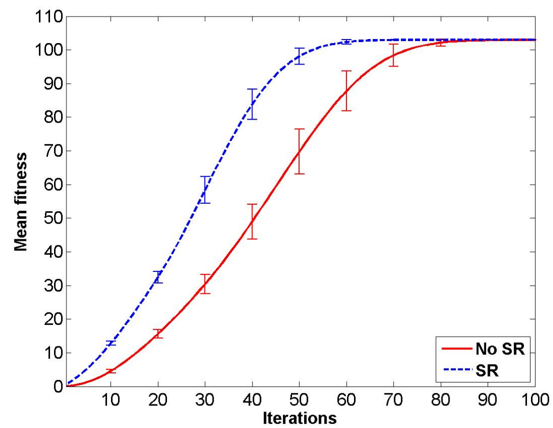

Figure 1: This graph plots the mean fitness of implemented actions across all agents over the duration of the run without chaining, with and without social regulation.

The diversity, or number of different ideas, exhibited an increase as the space of possibilities is explored followed by a decrease as agents converge on fit actions, as shown in Figure 2.

This pattern is typical in evolutionary scenarios where outputs vary in fitness. What is of particular interest here is that this pattern occurred earlier, and was more pronounced, in societies with SR than in societies without it Inferior creators were evidently inventing the same ideas so decreasing their creativity had little effect on diversity. On the other hand, superior creators were diverging variety of different directions, so making them more creative did increase diversity.

As illustrated in Figure 3, in societies with SR, while all agents initially invented and imitated with equal frequency, encouraging effective creators to create and discouraging ineffective creators did eventually cause them to segregate into two distinct groups: one that invented, and one that imitated. Thus whereas any point along the pareto frontier was optimal behaviour from an individual standpoint, they all piled up at the extreme ends, and the society as a whole benefited from this division of labour.

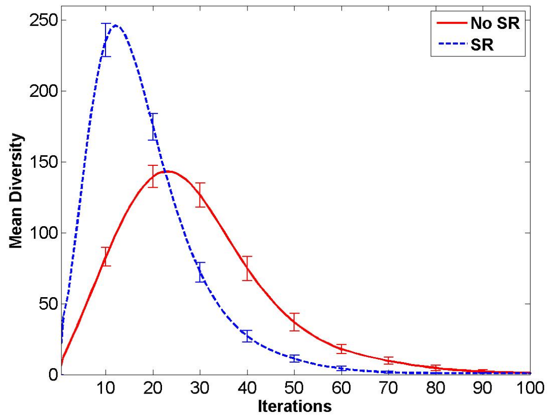

Figure 2: This graph plots the mean diversity of implemented actions across all agents over the duration of the run without chaining, with and without social regulation.

Thus the observed increase in fitness can indeed be attributed to increasingly pronounced individual differences in degree of creativity over the course of a run; agents that generated superior cultural outputs had more opportunity to do so, while agents that generated inferior cultural outputs became more likely to propagate proven effective ideas rather than reinvent the wheel.

The Effect of Social Regulation with Chaining

With chaining turned on, cultural outputs got increasingly fitter over the course of a run, as shown in Figure 4. This is because a fit action could always be made fitter by adding another sub-action. Note that with chaining turned on, although the number of different actions decreases, the agents do not converge on a static set of actions; the set of implemented actions changes continuously as they find new, fitter actions.

As was the case without chaining, the diversity of ideas with chaining turned on exhibited an increase as the space of possibilities is explored followed by a decrease as agents converge on fit actions, and once again this pattern was more pronounced in societies with SR than in societies without it, as shown in Figure 5. Interestingly, however, diversity no longer peaks later for non-SR than SR. Because with the capacity to chain simple ideas into increasingly complex ideas, the pool of possible ideas is now unconstrained, it no longer makes sense to converge quickly on optimal ideas. Indeed, there no longer is a fixed set of optimal ideas.

As was the case in the experiments without chaining, societies with SR ended up separating into two distinct groups: one that primarily invented, and one that primarily imitated.

Discussion

The goal of this paper was not to develop a realistic model of creativity but to investigate whether, with respect to creativity, can there be too much of a good thing. Are the needs

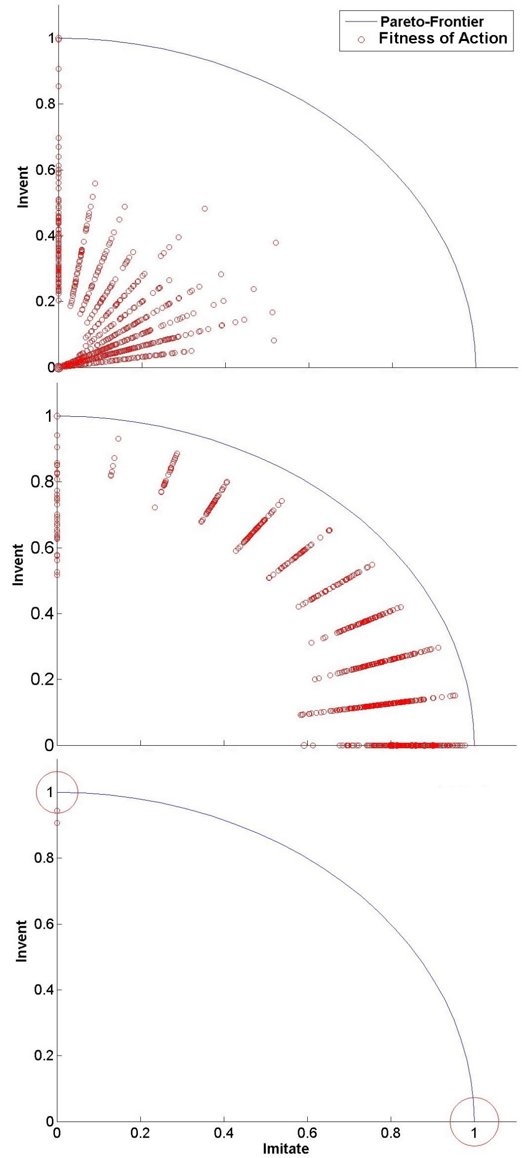

Figure 3: This graph plots the fitness of actions obtained through invention on the y axis and through imitation on the x axis. Fitness values are given as a proportion of the fitness of an optimally fit action. The pareto frontier indicates the range of possible ways an agent can behave optimally, either by always inventing optimally (upper left corner) or always implementing an optimal action obtained by imitating a neighbour (bottom right corner) or by implementing optimal actions obtained through some combination of inventing and imitating (all other points along the curve). Each small red circle shows the mean fitness of an agent's actions obtained through invention and imitation averaged across ten iterations: iterations 1 to 10 in the top graph, 25 to 35 in the middle graph, and 90 to 100 in the bottom graph. Since by iteration 90 all values were piled up in two spots – the upper left and the bottom right – they are indicated by large red circles at these locations.

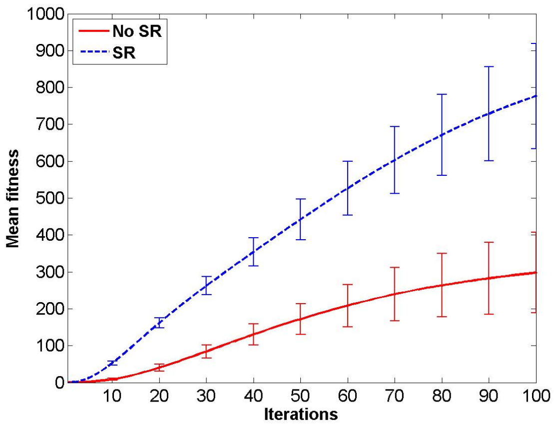

Figure 4: This graph plots the mean fitness of implemented actions across all agents over the duration of the run with Chaining turned on, with and without social regulation.

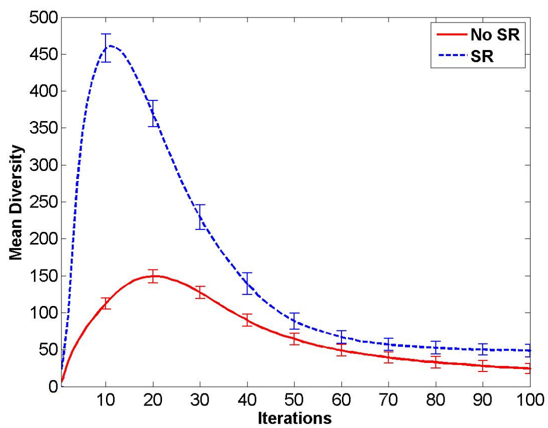

Figure 5: This graph plots the mean diversity of implemented actions across all agents over the duration of the run with Chaining, with and without social regulation.

of the individual for creative expression at odds with society's need to reinforce conventions and established protocols? EVOC agents are too rudimentary to suffer the affective penalties of creativity but the model incorporates another drawback to creativity: time spent inventing is time not spent imitating. Because creative agents spend their time inventing new ideas at the expense of social learning of proven ideas, effectively rupture the fabric of the artificial society; they act as insulators that impede the diffusion of proven solutions. Imitators, in contrast, serve as a "cultural memory" that ensures the preservation of successful ideas. When effective inventors created more and poor inventors created less, the society as a whole could capitalize on the creative abilities of the best inventors and capitalize on efforts of the rest to disseminate fit cultural outputs. This effect was temporary when agents were limited to a finite set of simple ideas; in other words, when the set of possible ideas was finite, the benefits of self-regulated creativity were short-lived. However, when agents were able to chain simple ideas into complex ideas and thus the space of possible ideas was open-ended, the benefits of self-regulation of creativity increased throughout the duration of a run. The results suggest that it can be beneficial for a social group if individuals are allowed to follow different developmental trajectories in accordance with their demonstrated successes, but only if the space of possible ideas is open-ended enough that there are always avenues for new creative ideas to explore.

It has been suggested that the capacity to chain together ideas for simple actions to generate ideas for complex actions such that the space of possible ideas was open-ended emerged some 1.7 million years ago, around the time of the transition from *Homo habilis* to *Homo erectus* (Donald 1991). This hypothesis is supported by mathematical (Gabora and Aerts 2009; Gabora and Kitto 2013) and computational (Gabora and Saberi 2011; Gabora and DiPaola 2012; Gabora, Chia, and Firouzi 2013) modelling. The fact that self-regulation of creativity was only found to be of lasting value in societies composed of agents capable of chaining suggests that there may have been insufficient selective pressure for self-regulation of creativity before this. Thus, prior to this time there would have been little individual variation across individuals in a social group with pronounced individual differences in creativity emerging after this time.

These results do not prove that in real societies successful creators invent more and unsuccessful creators invent less; they merely show this kind of self-regulation is a feasible means of increasing the mean fitness of creative outputs. However, the fact that strong individual differences in creativity exist (Kaufman 2003; Wolfradt and Pretz 2001) suggests that this occurs in real societies. Whether prompted by individuals themselves or mediated by way of social cues, families, organizations, or societies may spontaneously self-organize to achieve a balance between creative processes that generate innovations and the imitative processes that disseminate these innovations. In other words, they evolve faster by tempering novelty with continuity. A more complex version of this scheme is that individuals find a task at which they excel, such that for each task domain there exists some individual in the social group who comes to be best equipped to explore that space of possibilities.

The social practice of discouraging creativity until the individual has proven him- or herself may serve as a form of social self-regulation ensuring that creative efforts are not squandered. Individuals who are tuned to social norms and expectations may over time become increasingly concerned with imitating and cooperating with others in a manner that promotes cultural continuity. Their thoughts travel more well-worn routes, and they are increasingly less likely to innovate. Others might be tuned to the demands of creative tasks, and less tethered to social norms and expectations, and thereby more likely to see things from unconventional perspectives. Thus they are more likely to come up with solutions to problems or unexpected challenges, find new avenues for self-expression, and contribute to the generation of cultural novelty. In other words, what Cropley *et al.* (2010) refer to as the "dark side of creativity" may reflect that the creative individual is tuned to task needs at expense of human needs. Although in the long run this benefits the group as a whole because it results in creative outputs, in the short run the creative individual may be less likely to obey social norms and live up to social expectations, and to experience stigmatization or discrimination as a result, particularly in his/her early years (Craft 2005; Scott 1999; Torrance 1963). Once the merits of such individuals' creative efforts become known, they may be supported or even idolized.

Limitations of this work include that the fitness function was static throughout a run, and agents had only one action to optimize. In real life, there are many tasks, and a division of labor such that each agent specializes in a few tasks, and imitates other agents to carry out other tasks. It may be that no one individual is an across-the-board "creator" or "imitator" but that different individuals find different niches for domain-specific creative outputs.

Another limitation is that currently EVOC does not allow an agent to imitate some features of an idea and not others. This would be useful because cultural outputs both in EVOC and the real world exhibit a version of what in biology is referred to as epistasis, wherein what is optimal with respect to one component depends on what is going on with respect to another. Once both components have been optimized in a mutually beneficial way (in EVOC, for example, symmetrical arm movement), excess creativity risks breaking up co-adapted partial solutions. In future studies we will investigate the effects of enabling partial imitation.

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