What Happens When a Computer Joins the Group?

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Abstract

We consider the advent of computational creativity systems that are potentially far superior to human creators, at least in some domains. To do so, we revisit the concepts of P- and H-creativity and propose a social refinement called *group-relative creativity (G-creativity)*. Using this reconceptualization, we explore several critical questions regarding computational creativity's effect on human creators.

Introduction

On November 19, 2019, the world was shocked by the sudden and premature retirement of South Korean Go player, Lee Sedol. Sedol, an 18-time world Go champion of 9-dan rank (the highest rank in the game), made headlines in 2016 when he was defeated 4-1 in a match against AlphaGo, a Go playing computer program developed by Google DeepMind. Sedol's defeat at the "hands" of AlphaGo marked the first time a computer had beaten a 9-dan professional, and it left both Sedol and the rest of the world stunned.

Of his retirement, Sedol said:

> *With the debut of AI in Go games, I've realized that I'm not at the top even if I become the No. 1 through frantic efforts. Even if I become the No. 1, there is an entity that cannot be defeated. Frankly, I had sensed kind of a defeat even before the start of the matches against AlphaGo. People from Google's DeepMind Technologies looked very confident from the beginning.* (Yonhap News Agency 2019)

Sedol's defeat and subsequent retreat from professional Go playing was for many a cause for alarm:

> *Sedol's final bow in professional Go signals a more significant, existential concern. If a world champion, floating at the peak of personal achievement, starts to view human accomplishment and machine accomplishment as one and the same, it creates an environment for frustration, disappointment, and perceived loss of purpose. Sedol sits at the edge of this realization, but all of us are not far behind.* (Pranam 2019)

How did the AlphaGo system designers respond to Sedol's retirement? DeepMind's CEO Demis Hassabis credited Lee with showing "true warrior spirit" and then stated:

> *On behalf of the whole AlphaGo team at DeepMind, I'd like to congratulate Lee Sedol for his legendary decade at the top of the game, and wish him the very best for the future ... I know Lee will be remembered as one of the greatest Go players of his generation.* (Vincent 2019)

Without wishing to lay blame, one cannot help but sense a sort of eulogy in these words, not so much for Lee Sedol as for the era when humans ruled the world of Go. Sedol's fatalistic retirement and the near-condescending reactions of DeepMind and others betray a sense that we as a society have in some ways already accepted the inevitability of computational domination and at the same time have failed to anticipate and prepare adequately for the consequences of super-human AI and CC systems. And so we pose these questions:

- Do we risk destroying human creativity by creating systems that are more creative than humans?
- Are we as CC researchers doing our due diligence to anticipate the potentially negative impacts that our systems will have on human creativity?
- Are we prepared to take responsibility for these impacts?

Figure 1: Lee Sedol retired as a professional player after being defeated by AlphaGo. *Photo by Google via Getty Images.*

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- What can be done to mitigate any negative consequences of CC on human creativity?

Though technological advancement is often a boon for humanity, there are well-known exceptions to this, cases in which such advances are at least correlated with the development of human deficits, displacements from jobs, etc. Factory automation has eliminated many manufacturing jobs; keyboards have eliminated the need for penmanship; GPS means that people don't learn how to read maps or navigate using waypoints and landmarks; spelling and grammar checkers mean people don't develop mental models of syntax and grammatical structure; and recent research even suggests that our reliance on the internet for all things information promotes cognitive offloading and may result in negative effects on problem solving, recall and learning abilities (Storm, Stone, and Benjamin 2017).

It has historically been the case that such deficits and displacements disproportionately affect the under-educated. And, while the negative effects are very real for the displaced, they have been largely temporary and transient because they could be compensated for, over time, with additional educational interventions. However, an interesting recent study on the future impact of AI on workers suggests a new trend—for the first time, a major technology (AI) will have the most effect on well-educated, white collar workers (Muro, Whiton, and Maxim 2019). How should we react when education may no longer be the solution? Because CC is still in its infancy and due to the challenging nature of its ultimate goals, one may be tempted to assume that we are not yet facing these issues vis à vis creativity; however, we argue that AlphaGo *is* a CC system—and a dominant one—and that even for CC, these issues are contemporary and unavoidable.

Super-human CC is here, now

Though enjoyed by more than 40 million people worldwide (most in Asia), with a history going back $2,500$ years, Go was largely unknown to most of the world until the fateful match between Sedol and AlphaGo. In the game, players take turns placing black or white stones on a 19×19 grid to capture opponent's pieces or to surround empty territories. Go was chosen intentionally as the next great challenge for computational intelligence because despite seeming simple, the game allows for more possible moves than atoms in the known universe, making traditional "brute force" AI methods an impossibility (Pranam 2019). Experts widely believed that Go could not be solved in the way that other games (such as chess) have been.

AlphaGo is a unique example of a computational system that has exceeded human abilities in ways that even unbiased humans readily acknowledge. AlphaGo doesn't just beat humans, it consistently beats even the very best of human Go players. This phenomenon is especially marked because the problem of playing Go possesses a unique characteristic that many other creative domains lack: given any two Go players, there exists a well-defined and universally-recognized way of comparing them (i.e., which one wins a game they play against each other).

Because this is at least not so clearly the case in many CC domains, it seems appropriate to ask whether Go, in fact, represents a creative domain and therefore whether AlphaGo can, in fact, be considered a computationally creative system.

In order to address this, we can test AlphaGo against two common ways of defining computational creativity. The first, due to Colton and Wiggins (2012) defines CC as

> *The philosophy, science and engineering of computational systems which, by taking on particular responsibilities, exhibit behaviours that unbiased observers would deem to be creative.*

Is playing Go a behavior that is deemed to be creative?

Go is considered an art form in Asian cultures, one that not only allows creativity but also demands it. Consider this from European Go champion Fan Hui:

> *As we walk the path of improvement, we must study and experience all aspects of the game: joseki, fuseki, shape, and direction, just to name a few. After we absorb this knowledge, we learn over time to apply it flexibly. But to reach the level of grandmasters, even this is not enough! As we gain experience, our knowledge fetters our creativity. To truly throw off these shackles and liberate ourselves from what we have learned, we must discard labels of "right" and "wrong." In their place, we must consider the essence of Go: the role of each stone, and the relationships between them. Only in this way can we reach the level where invention prevails over tradition. AlphaGo began from the same fundamentals as humans, but the rigid attachment to knowledge is simply not in its nature.* (Baker, Hubert, and Graepel 2016)

Or, this from Lee Sedol himself:

> *It made me question human creativity. When I saw AlphaGo's moves, I wondered whether the Go moves I have known were the right ones. Its style was different, and it was such an unusual experience that it took time for me to adjust.* (Choe 2016)

For those who play Go, creativity is considered a fundamental aspect of the game.

A second common way to define computational creativity is by using common *attributes* of creativity. Can it be demonstrated that AlphaGo's choice of moves exhibits novelty, value, surprise, and intentionality—attributes frequently used to characterize computational creativity? Does it generate behavior through computational means that are deemed novel, surprising, valuable, and intentional?

Consider the following analysis of two key points in the match between AlphaGo and Sedol:

> *In Game Two, the Google machine made a move that no human ever would. And it was beautiful. As the world looked on, the move so perfectly demonstrated the enormously powerful and rather mysterious talents of modern artificial intelligence.*
>
> *But in Game Four, the human made a move that no machine would ever expect. And it was beautiful too.*

Indeed, it was just as beautiful as the move from the Google machine—no less and no more. It showed that although machines are now capable of moments of genius, humans have hardly lost the ability to generate their own transcendent moments. And it seems that in the years to come, as we humans work with these machines, our genius will only grow in tandem with our creations. (Metz 2016)

It seems clear that by widely-accepted standards, the game of Go is considered a creative domain and AlphaGo indeed constitutes a computational creative system. In other words, *computational systems that exceed human levels of creativity are already a reality, and we are likely to see an increasing number of such systems in an increasing number of creative domains*.

Comparison in Creative Domains

It may be argued that perhaps the creative domain of Go is somewhat unique because it offers a well-defined and universally accepted method for the direct comparison of (the creativity of) individuals. The natural assumption may be that most creative domains do not offer such a comparative mechanism and that thus human creators in most domains may not be as susceptible to the kind of disruptive comparison to which Lee Sedol was exposed. However, we argue that most, if not all, creative domains are subject to the effects of some kind of comparative mechanism, at least implicitly (and for many, it is actually quite explicit), even if they are not as overtly competitive as is the domain of Go.

In other words, people can and do make creative comparisons (or indirect surrogates of such) all the time. Consider things such as which work garners the most viewers/attention/citations, sells for the most money, wins an award (or competition, even!) Given two artifacts from a domain, people can almost always be coerced into choosing which they prefer. Anytime creativity is rewarded/incentivized in a non-uniform way, it becomes, in some sense, an optimization problem, and therefore one of comparison. In some domains, such comparisons may be subtle and even latent and may have little (perceived) measurable affect. However, in many domains these comparisons result in competition for recognition, awards, employment, etc. The result is very often a natural sense of success/failure attached to creative endeavor. Thus, the issue at the heart of Lee Sedol's "crisis of faith" may soon threaten creators in many other domains because *all creative domains include at least an implicit element of comparison and many include an explicit competitive component.*

How Should We Think About This?

Computational creativity theory provides the lens through which we typically view the world of CC systems; can it help us make sense of the effect that (dominant) CC systems may have on humans, particularly their creativity? We suggest an advantage in this respect for a more nuanced view.

P-creativity and H-creativity Directly relevant to the discussion of Lee Sedol is the notion of personal versus historical creativity. Personal or *P-creativity* represents behaviors or concepts that are novel to their creator, but may not be novel in the broader society. Historical or *H-creativity*, by contrast, refers to behaviors or concepts that *are* novel within the broader society (Boden 1992). Though P-creativity is prerequisite to H-creativity, few instances achieve the status of being H-creative. Like many creative professionals, Sedol had devoted his career to the pursuit of H-creativity.

In his announcement last November, Sedol was very specific about his reasons for giving up the hunt for H-creativity. It was not merely that he had been defeated, but that in his estimation, an entity had entered the field that "cannot be defeated"—he believed that H-creativity was no longer a possibility for him or any other human. Is the introduction of a computational agent into a community somehow fundamentally different than the introduction of another human agent? If so, how? What about this scenario is different, say, than when Lee Sedol loses to another really great human player like Lee Chang-ho (the only human player currently ranked higher than Lee Sedol)? Why don't other human players evoke the same reaction as AlphaGo does?

An apt analogy may be found in Csikszentmihalyi's (Csikszentmihalyi and Csikszentmihalyi 1992) flow model. In the model, a sense of "flow" (meaning a state of energized focus) is achieved when an individual addresses high levels of challenge with equally high levels of skill (see Figure 2). Certainly H-creativity occurs within these same parameters, and individuals do not remain static within the model. As

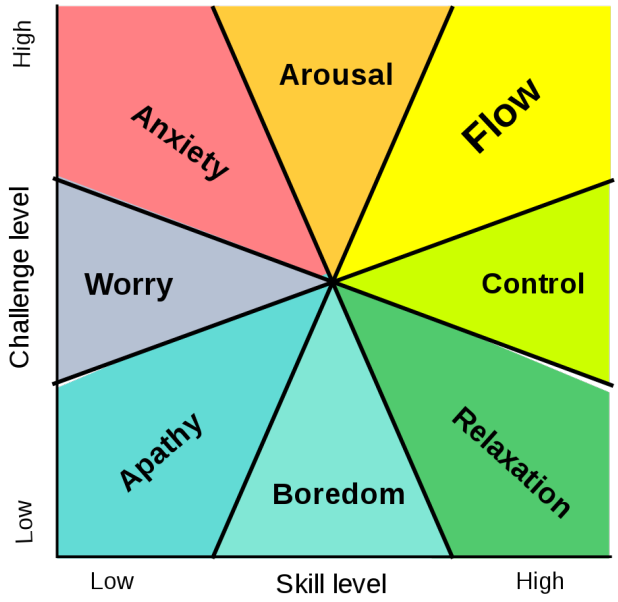

Figure 2: As CC systems improve in their ability to compete with human creativity, humans may begin to feel that the level of challenge for producing novelty and value exceeds humanly-capable skill levels. This scenario, as represented in Csikszentmihalyi's flow model (Csikszentmihalyi and Csikszentmihalyi 1992), leads to anxiety and doubt, which if left unabated leads to diminished human creativity.

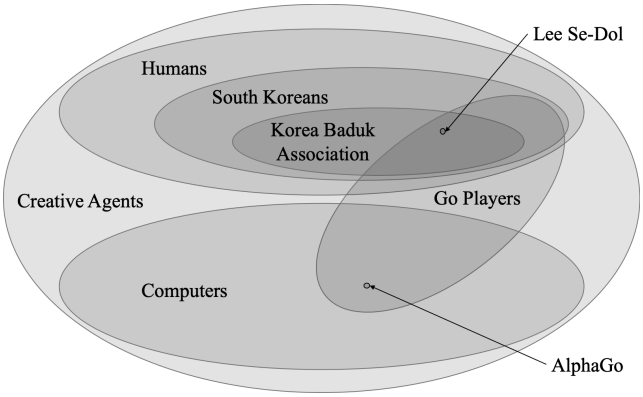

Figure 3: A snapshot in time of some of the various communities to which Lee Sedol belongs. Sedol's creative behaviors are differentially evaluated for historical creativity in each of these contexts. Though Sedol's prospects for H-creativity were impacted by the creation of AlphaGo in the context of one of these communities, his contributions maintain significant H-creative value in many (if not most) other communities. Discouragement and disillusionment may be more likely to arise when an individual's perception of (their own) creativity is focused on the prospect for H-creativity in a single, particular community rather than across multiple communities.

skill increases, the perception of challenge decreases such that over time the level of challenge must also rise commensurate with the level of skill in order to maintain the "flow" experience. Of interest in our discussion is what occurs when the level of challenge increases at a rate that the individual's level of skill is unable to match. In this scenario, the individual tends towards anxiety and worry until either the skill level can be increased or the individual quits the endeavor altogether.

In presenting his framework for CC systems, Wiggins describes a state of limbo that he calls *generative uninspiration*. In this state, "the technique of the creative agent does not allow it to find valued concepts" (2006). Can it be that computational creativity inadvertently contributes to generative uninspiration in humans? Wiggins' solution to this problematic scenario is that the system (or in this case, the human) must undergo *transformational creativity*, or in other words, change its method for generating new artefacts. However, even according to Wiggins, the method for doing so is non-trivial, and for some domains may seem humanly impossible.

Rethinking P- and H-Creativity

Because we are interested in creativity in the context of a community whose membership is changing (i.e., by the addition of CC systems), the concepts of P- and H-creativity need some reformulation in order to account for this sociality. To this end, we begin by exploring the relationship between P- and H-creativity.

Let the function $P_i : D \mapsto \{0, 1\}$ be an indicator function that maps artefacts from a domain D to a Boolean value such that $P_i(x) = 1$ indicates that an artefact $x \in D$ is P-creative for an individual i. [1]

Consider next a similar indicator function $H_i : D \mapsto \{0, 1\}$ for H-creativity such that $H_i(x) = 1$ indicates that an artefact $x \in D$ is H-creative for individual i. Here we encounter a problem that has not been adequately addressed regarding H-creativity—with respect to what context is H computed? Is it truly *historical*, meaning that $H_i(x) = 1$ indicates that individual i has created x for the first time in any context? Or, is it merely *universal*, meaning that $H_i(x) = 1$ indicates that, amongst the set I of all agents, i is credited with the "invention" of x? Or, is it limited further, such that $H_i(x) = 1$ indicates that, amongst some set $C \subset I$, i is the creator of x?

For the moment, let us assume that $H_i(x) = 1$ indicates that, amongst some set $C \subseteq I$, i is the first to have created x. At one extreme, when $C = \{i\}$,

$$\forall(x), P_i(x) = H_i(x)$$

However, as the size of C increases, how can we characterize the relationship between P and H, or between P-creativity and H-creativity?

P-creativity represents creativity in the limited societal context of a single individual. H-creativity has been used to represent creativity in a more global societal context. Neither of these designations properly facilitate the characterization of creative behavior as it occurs simultaneously in the context of several nested and overlapping societal contexts (consider, for example, some of Lee Sedol's group memberships, shown in Figure 3). In the context of a singleton group consisting of a single creator, all creative acts are both P-creative and H-creative [i.e., $p(P_i(x) = H_i(x)) = 1.0$]; however, as additional creators join the group, the likelihood of any creative act by any individual being H-creative decreases (see Figure 4).[2]

Note that this decline in an agent's ability to make "meaningful" creative contributions to the group may follow many profiles, as shown in the figure. The actual shape of the decline profile is both group- and individual-specific and will be affected by complex group dynamics, including membership demographics, group history, the domain in which the group is creating, group sociability, cohesion, and cooperation, to name a few. Exploring the relationship between these group characteristics and the shape of these contribution profiles suggests interesting research questions, but we commend those to future work.

Here, we focus instead on the fact that no matter the shape, the curves will always be monotonically decreasing with group size and note that here, too, there is a complex interplay involving group dynamics—for example, on the one hand, the larger the group, the less likely it is that a

[1] It may be interesting to alternatively consider this to be a real-valued function $G_i : D \mapsto [0, 1]$, but for now we will consider the Boolean case, which may be more consistent with classical treatments of P- and H-creativity.

[2] This does not account for the sometimes confusing use of H-creativity in a temporal sense, as a measure of truly historic (and thus group-agnostic) creativity.

particular individual agent may make an important contribution; on the other hand, however, the larger the group, the more likely it is that significant creative advances are made by *some* agent, building on earlier the successes of group members. Again, we leave these kinds of research questions for the future.

In connection with the inverse relationship between likelihood of individual contribution and group size, we posit a *satisficing threshold* θ on $p(P_i(x) = H_i(x))$, specific to an individual, above which that individual is satisfied with their likelihood of contribution (also shown in Figure 4). Presumably, any group member gains some benefit as a member of the group—social connection, cooperation, learning, encouragement, challenge, critique, camaraderie; θ represents a cost that the member is willing to pay for these group benefits, and the intersection of the individuals contribution curve with their satisficing threshold, indicates a break-even point for group membership. We re-emphasize that both the threshold and contribution curve are group-relative and individual-specific. That is, they only have meaning relative to a group, and each group member has a unique valuation for group membership. Figure 5 shows one way to characterize creator type based on the interplay between an individual's satisficing threshold for meaningful contribution and the shape of their likelihood curve for such contribution.

This idea of creativity *relative to* a specific community or group is related to ideas that go back at least to Csikszentmihalyi's systems view of creativity, in particular his notion of field (1988). While other authors have since worked on operationalizing this social model in various ways, such work has focused on the behavior of the society (Sosa and Gero 2005) and on the society's (dynamic) conceptualization of the domain (meaning, broadly, how it understands what is in the domain, what is valuable in the domain and how to explore the domain) (Linkola and Kantosalo 2019).

By contrast, what is wanted here is some way to talk about a society's *beliefs about itself*. This is actually somewhat more related to Jennings's social structure for creative agents, in which he employs a theory-of-mind and agent affinities; but, again, his aim is to explain creative behavior (2010).

We take an approach reminiscent of Jennings's—given that we want to measure creativity relative to a community, it makes sense that the members of that community are involved in that measurement. In doing so, we offer a notion intermediate to P- and H-creativity that explores their reciprocal relationship, which we call *group-level creativity* or G-creativity.

G-Creativity

For a community of individuals, C, domain D, $i, j \in C$ and $x \in D$, define a family of indicator functions:

$$G_{ij} : D \mapsto \{0, 1\}$$

that map artefacts from a domain D to the Boolean set, indicating agent i's belief in agent j's creativity in producing artifact x. Note this judgement purposely does not differentiate a personal vs. group creativity—it is simply a belief

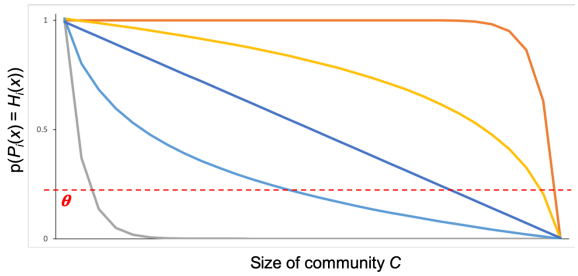

Figure 4: The relationship between an individual's likelihood of meaningful contribution and the size of the community of which the individual is a member. In a statistical sense, the larger the community, the less likely any single contribution for any single individual is considered H-creative. This functional decline could take many forms (depending on i, x, C) but is always monotonically decreasing. The threshold θ represents a valuation of group membership.

indicator, parameterized both by critic and creator.[3]

Given this family of indicator functions, and following Jennings' example of generalizing beliefs, we can now compute a significant number of group-relative creativity measures that are more nuanced treatments of distinct ideas, which are conflated in the traditional conception of P- and

[3]Note that when necessary, the group identity can be indicated using a superscript, as $G^C_{ij}(x)$, but for parsimony, when group identity is clear from context, we will avoid this.

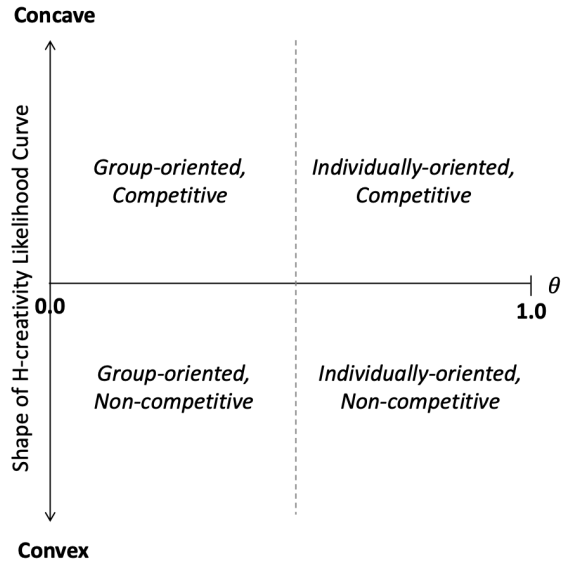

Figure 5: The satisficing threshold, θ, and the shape of the likelihood curve for H-creativity on a scale from convex (e.g., the grey curve in Figure 4) to concave (e.g., the red curve) for a particular individual in a community characterize their group-mindedness and competitiveness in the community.

H-creativity. These new measures allow for both individual and collective creativity and beliefs about both types of creativity by both the individual and the group. We can marginalize any of the variables to produce these various *viewpoints* on creativity. For example, $G_{ij}(\cdot) = \frac{1}{|D|}\sum_x G_{ij}(x)$ represents agent i's belief about the creativity of agent j, independent of artifact.[4]

Perhaps the most salient viewpoints for the current discussion are an individual's belief about their own (group-relative) creativity:

$$G_{ii}(\cdot) = \frac{1}{|D|}\sum_x G_{ii}(x)$$

and the community's belief about an individual's (group-relative) creativity:

$$G_{\cdot j}(\cdot) = \frac{1}{|C||D|}\sum_i\sum_x G_{ij}(x)$$

The former is the viewpoint affecting Lee Sedol's decision to retire from competitive Go—his belief about his own creative potential was adversely affected by his encounter with AlphaGo. This disruptive event introduced a precipitous drop in his estimation of his own creativity,[5] driving it prematurely below his satisficing threshold. The latter viewpoint, that of the community's estimation of Sedol's creativity, was not so adversely affected; indeed, according to some commentators, Lee Sedol may in some way now be viewed as *more* creative, given his remarkable victory in game 4.

This reconceptualization of how we characterize creativity allows for a nuanced treatment of many issues, most particularly those raised here arising from the concern about the effect of dominant CC systems. *The refined concept of G-creativity provides a socially relative formalization that spans the spectrum naturally demarcated by the classical concepts of P- and H-creativity*. For a catalogue of concepts resulting from this formalization, see the Appendix.

Discussion

This more nuanced view of characterizing creativity, with a social lens, suggests many avenues for discussion, of which we mention a few that we find compelling.

First, because G is parameterized by community and individual, it can provide a rich representation of the concept of creativity. In particular, each such parameterization provides a different viewpoint. And, therefore, any characterization/evaluation by any entity (individual or group) of creativity should take into account these multiple viewpoints—the assessment of creativity is an agglomeration of multiple individual and group beliefs regarding the artifact, act, individual or group in question. In the context given here, we have so far mostly maintained a community-centric perspective—considering creativity from a single, fixed group membership; however, it is equally plausible to consider things from an individual-centric one, recognizing that an individual may be a member of multiple communities. This would necessarily introduce additional generalized viewpoints of creativity, for example, marginalizing over an individual's group memberships. In other words, *all* creativity has value in *some* community and failure to consider creativity from different viewpoints and across different societies results in a failure to effectively assess (an individual's) creativity.

Second, in the context of a community of creators, it is not clear what group membership entails. What is required for an individual to feel like they are a member of the group, and what is required for the group to accept them as such? While a satisfactory answer to this question is beyond the scope of this treatment, for the purpose of discussion, we suggest that the answer is likely to include things like empathy/understanding, communication, cooperation, mutual admiration/inspiration. Given this, a natural question is whether a CC system can ever meet such a standard?[6,7] Can a CC-system share common experiences with other members of a group? Or inspire or be inspired by other members of a group? Note, that while in the general case, such groups may consist entirely of artificial agents, we are here most interested in groups with human members. So, can a CC system inspire *human* creativity the way human creativity inspires human creativity? Does AlphaGo inspire? Or just discourage? Are those two versions of the same thing? Humans have an intrinsic (emotional?) connection with each other by virtue of sharing a common species, something they do not naturally have with computational systems. If CC systems are to be considered members of a group (that includes humans), is this kind of connection necessary, and is it something we really want to encourage? Also, assuming it is possible for CC systems to be members of a group, is the introduction of a computational agent into a (human) community somehow fundamentally different than introducing another human agent? If so, why? Why is Lee Sedol's reaction to his experience with AlphaGo so different than his experience with losing to Lee Chang-ho? Why doesn't this make him feel like he feels about AlphaGo?

Third, as CC systems continue to advance, they will begin competing for people's jobs, especially in the realms of content creation; we have already seen the development of systems for producing music (Carré, Pachet, and Ghedini 2017) and soundtracks (Brown 2012), video game assets (Hello Games 2016), logo (Sage et al. 2018) and slogan generation (Gatti et al. 2015), and news articles (Montal and Reich 2017), to name a few. As computational resources become cheaper and these systems become more advanced, it is likely that employment opportunities for human creatives will be negatively impacted. To the extent that we, as a field, care about the impact our work may have on society and the resulting attitudes society may have about our

[4] Operationally, the denominator of the normalization term will likely be approximated as $|X|$, where $X \subset D$.

[5] Actually, based on one of the quotes above, his estimation of human creativity in general, represented by the viewpoint $G_{i\cdot}^{human}(\cdot)$, may have been adversely affected as well.

[6] This is currently a common critique of CC systems purporting to work in artistic domains—extant systems have no sense of community.

[7] Interestingly, after AlphaGo defeated Lee Sedol, the Korean Baduk Association awarded it an honorary ranking of 9-dan, equal to that of Sedol, for its "sincere efforts" to master Go's Taoist foundations and reach a level "close to the territory of divinity".

work, it is important to consider these "mundane" creative impacts as well as the grander ones illustrated by cases such as AlphaGo. Perhaps as a field we should focus on domains in which supplanting people would be welcome (dangerous tasks or curing cancer); or on domains where finding qualified/interested human applicants is difficult (programming, teaching); or on nascent domains for which competition is low (virtual reality)? Certainly as a community we must accept the challenge to continuously and carefully articulate why CC is justifiable as a field of research—i.e., how does CC benefit humanity enough to justify its negative impacts?

Finally, perhaps the right approach is a focus on co-creative systems that complement rather than compete with human abilities or on systems that teach creativity. Imagine a system that could teach what it knows about Go. Perhaps one way to ameliorate some of the potential negative impact of a CC system is the requirement that the system be able to explain its creativity (Bodily and Ventura 2018). Is it possible that the assumption by CC systems of creative responsibilities that are primarily exploratory in nature could facilitate advances in transformational creativity by humanity, as humans move towards new forms of creativity that avoid competing with CC systems on unfavorable terms? Could such an evolutionary effect result in a change in the rate at which transformational creativity occurs? Could CC systems become the Iron Giants on whose shoulders the next Newtons stand?

Conclusion

We have argued that

(a) CC systems that supercede human-level creativity are becoming a reality, and it is urgent that the community begin thinking about the implications of this,

(b) (almost) all creative domains include some natural level of competition/comparison and therefore any creators in those domains are susceptible to being affected by dominant CC systems operating in that domain, and

(c) G-creativity offers a reconceptualization of the notions of P- and H-creativity that provides us a more fine-grained set of tools with which to wrestle with points (a) and (b).

We've demonstrated the utility of these tools in raising questions and making suggestions about the affects that dominant CC systems may have on their domains of expertise and on their human peers.

References

Baker, L.; Hubert, T.; and Graepel, T. 2016. Google DeepMind challenge match. https://deepmind-media.storage.googleapis.com/alphago/pdf-files/english/ls-vs-ag2/LS%20vs%20AG%20-%20G2%20-%20English.pdf.

Boden, M. 1992. *The Creative Mind*. London: Abacus.

Bodily, P., and Ventura, D. 2018. Explainability: An aesthetic for aesthetics in computational creative systems. In *Proceedings of the 9th International Conference on Computational Creativity*, 153–160.

Brown, D. 2012. Mezzo: An adaptive, real-time composition program for game soundtracks. In *Proceedings of the 1st International Workshop on Musical Metacreation*, 68–72. AAAI Technical Report WS-12-16.

Carré, B.; Pachet, F.; and Ghedini, F. 2017. Daddy's car: A song composed by artificial intelligence—in the style of the Beatles. `https://www.youtube.com/watch?v=LSHZ_b05W7o`.

Choe, S.-H. 2016. Google's computer program beats lee se-dol in go tournament. *The New York Times*. https://www.nytimes.com/2016/03/16/world/asia/korea-alphago-vs-lee-sedol-go.html.

Colton, S., and Wiggins, G. A. 2012. Computational creativity: The final frontier? In *Proceedings of 20th European Conference on Artificial Intelligence*, 21–26.

Csikszentmihalyi, M., and Csikszentmihalyi, I. S. 1992. *Optimal Experience: Psychological Studies of Flow in Consciousness*. Cambridge university press.

Csikszentmihalyi, M. 1988. Society, culture, and person: A systems view of creativity. In Sternberg, R. J., ed., *The Nature of Creativity: Contemporary Psychological Perspectives*. Cambridge University Press. 325–339.

Gatti, L.; Özbal, G.; Guerini, M.; Stock, O.; and Strapparava, C. 2015. Slogans are not forever: Adapting linguistic expressions to the news. In *Proceedings of the International Joint Conference on Artificial Intelligence*, 2452–2458.

Hello Games. 2016. No Man's Sky. `https://www.nomanssky.com`.

Jennings, K. E. 2010. Developing creativity: Artificial barriers in artificial intelligence. *Minds and Machines* 20(4):489–501.

Linkola, S., and Kantosalo, A. 2019. Extending the creative systems framework for the analysis of creative agent societies. In *Proceedings of 10th International Conference on Computational Creativity*, 204–211.

Metz, C. 2016. In two moves, AlphaGo and Lee Sedol redefined the future. *Wired*. https://www.wired.com/2016/03/two-moves-alphago-lee-sedol-redefined-future/.

Montal, T., and Reich, Z. 2017. I, robot. you, journalist. Who is the author? *Digital Journalism* 5(7):829–849.

Muro, M.; Whiton, J.; and Maxim, R. 2019. What jobs are affected by AI? *Brookings Institution*. https://www.brookings.edu/wp-content/uploads/2019/11/2019.11.20_BrookingsMetro_What-jobs-are-affected-by-AI_Report_Muro-Whiton-Maxim.pdf.

Pranam, A. 2019. Why the retirement of Lee Se-Dol, former 'Go' champion, is a sign of things to come. *Forbes*. https://www.forbes.com/sites/aswinpranam/2019/11/29/why-the-retirement-of-lee-se-dol-former-go-champion-is-a-sign-of-things-to-come/#5fe95bb3887c.

Sage, A.; Agustsson, E.; Timofte, R.; and Van Gool, L. 2018. Logo synthesis and manipulation with clustered generative adversarial networks. In *Proceedings of the IEEE*

Conference on Computer Vision and Pattern Recognition, 5879–5888.

Sosa, R., and Gero, J. S. 2005. Social models of creativity. In *Proceedings of the International Conference on Computational and Cognitive Models of Creative Design VI*, 19–44.

Storm, B. C.; Stone, S. M.; and Benjamin, A. S. 2017. Using the internet to access information inflates future use of the internet to access other information. *Memory* 25(6):717–723.

Vincent, J. 2019. Former Go champion beaten by DeepMind retires after declaring AI invincible. *The Verge*. https://www.theverge.com/2019/11/27/20985260/ai-go-alphago-lee-se-dol-retired-deepmind-defeat.

Wiggins, G. A. 2006. A preliminary framework for description, analysis and comparison of creative systems. *Knowledge-Based Systems* 19(7):449–458.

Yonhap News Agency. 2019. (Yonhap interview) Go master Lee says he quits unable to win over AI Go players. *Yonhap News Agency*. https://en.yna.co.kr/view/AEN20191127004800315.

Appendix: Formalized concepts derived from G-creativity

Group-relative concepts of creativity that can be represented with a conceptualization of G-creativity. These concepts can be organized in various ways, and here we do so according to subject/object and individual/group. Given a community C, a domain D, agents $i, j \in C$ and artifact $x \in D$, we have the following:

A. Individual beliefs about individuals:

(1) $G_{ij}(x)$ is agent i's belief about agent j's creativity when producing x.

(2) $G_{ii}(x)$ is agent i's belief about their own creativity when producing x.

(3) $G_{ij}(\cdot) = \frac{1}{|D|}\sum_x G_{ij}(x)$ is agent i's belief about agent j's creativity in general (independent of a particular artifact).

(4) $G_{ii}(\cdot) = \frac{1}{|D|}\sum_x G_{ii}(x)$ is agent i's belief about their own creativity in general (independent of a particular artifact).

(5) $\mathrm{argmax}_x\, G_{ij}(x)$ identifies the artifact x that agent i believes is agent j's most creative work.[8]

(6) $\mathrm{argmax}_x\, G_{ii}(x)$ identifies the artifact x that agent i believes is its own most creative work.

(7) $\mathrm{argmax}_i\, G_{ij}(x)$ identifies the agent i with the highest opinion of agent j's creativity producing x; agent j's advocate/champion for x.

(8) $\mathrm{argmax}_i\, G_{ii}(x)$ identifies the agent i with the highest opinion of their own creativity producing x; the agent most certain they invented x.

(9) $\mathrm{argmax}_i\, G_{ij}(\cdot)$ identifies the agent i with the highest opinion of agent j's creativity in general (independent of a particular artifact); agent j's overall advocate/champion/admirer.

(10) $\mathrm{argmax}_i\, G_{ii}(\cdot)$ identifies the agent i with the highest opinion of its own creativity in general (independent of a particular artifact); the most self-confident member of the group.

(11) $\mathrm{argmax}_j\, G_{ij}(x)$ identifies the agent j of whom agent i has the highest opinion regarding their creativity producing x; the agent that agent i believes invented x.

(12) $\mathrm{argmax}_j\, G_{ij}(\cdot)$ identifies the agent j whom agent i considers to have the highest creativity in general (independent of a particular artifact); the agent that agent i most admires/reveres?

B. Individual beliefs about the group:

(13) $G_{i\cdot}(x) = \frac{1}{|C|}\sum_j G_{ij}(x)$ is agent i's belief about the community's creativity in producing x.

(14) $G_{i\cdot}(\cdot) = \frac{1}{|C||D|}\sum_j \sum_x G_{ij}(x)$ is agent i's belief about the community's creativity, independent of a particular artifact.

(15) $\mathrm{argmax}_x\, G_{i\cdot}(x)$ identifies the artifact x that agent i believes is the community's most creative work.

(16) $\mathrm{argmax}_i\, G_{i\cdot}(x)$ identifies the agent i with the highest opinion of the community's creativity producing x; perhaps the community advocate/champion/promoter for x.

(17) $\mathrm{argmax}_i\, G_{i\cdot}(\cdot)$ identifies the agent i with the highest opinion of the community's general creativity; the community advocate/champion/promoter.

C. Group belief about individuals:

(18) $G_{\cdot j}(x) = \frac{1}{|C|}\sum_i G_{ij}(x)$ is the community's belief about agent j's creativity when producing x.

(19) $G_{\cdot j}(\cdot) = \frac{1}{|C||D|}\sum_i \sum_x G_{ij}(x)$ is the community's belief about agent j's general creativity, independent of a particular artifact.

(20) $\mathrm{argmax}_x\, G_{\cdot j}(x)$ identifies the artifact x that the community believes is agent j's most creative work.

(21) $\mathrm{argmax}_j\, G_{\cdot j}(x)$ identifies the agent j of whom the community has the highest opinion regarding their creativity producing x; that agent that the community believes invented x.

(22) $\mathrm{argmax}_j\, G_{\cdot j}(\cdot)$ identifies the agent j whom the community thinks has the highest general creativity, independent of a particular artifact; the community "champion".

D. Group belief about the group:

(23) $G_{\cdot\cdot}(x) = \frac{1}{|C|^2}\sum_i \sum_j G_{ij}(x)$ is the community's belief about its collective creativity in producing x.

(24) $G_{\cdot\cdot}(\cdot) = \frac{1}{|C|^2|D|}\sum_i \sum_j \sum_x G_{ij}(x)$ is the community's belief about its collective general creativity, independent of a particular artifact.

(25) $\mathrm{argmax}_x\, G_{\cdot\cdot}(x)$ identifies the artifact x that the community believes is, collectively, its most creative work.

[8] Of course, argmax can be replaced with argmin for identifying concepts of "least".