Artificial Creativity Augmentation

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Abstract. Creativity has been associated with multifarious descriptions whereby one exemplary common definition depicts creativity as the generation of ideas that are perceived as both novel and useful within a certain social context. In the face of adversarial conditions taking the form of global societal challenges from climate change over AI risks to technological unemployment, this paper motivates future research on *artificial creativity augmentation* (ACA) to indirectly support the generation of requisite defense strategies and solutions. This novel term is of ambiguous nature since it subsumes two research directions: (1) artificially augmenting human creativity, but also (2) augmenting artificial creativity. In this paper, we examine and extend recent creativity research findings from psychology and cognitive neuroscience to identify potential indications on how to work towards (1). Moreover, we briefly analyze how research on (1) could possibly inform progress towards (2). Overall, while human enhancement but also the implementation of powerful AI are often perceived as ethically controversial, future ACA research could even appear socially desirable.

Keywords: Human enhancement · Artificial creativity · Safety

1 Deconstructing Anthropic Creativity

Creativity research has been described as a relatively understudied and underfunded field in psychology and neuroscience [25]. The term refers mostly either to research on creativity outcome being the contextualized evaluation of creative ideas (or artifacts) after their generation or to research on the creativity process itself related to the forerunning idea generation [53]. In this section, we examine both complex concepts and establish a possible scientific grounding for strategies on artificial creativity augmentation (ACA) to be addressed in Sect. 2.

1.1 Creative Outcome in Context

Many definitions for creativity have been formulated so far with the two-factor description of creativity as the generation of novel and useful ideas being one of the most commonly used in the related literature [39]. Already from this simple definition, it becomes apparent that creativity implies a perceiver to which

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something can appear novel or useful in the first place which provides a context to the evaluation of that thing in question. A further subjective account of creativity is reflected in a different three-factor definition of creativity [51] which relates creative ideas to their subjective originality, utility and surprisingness. On that view, novelty represents an imprecise creativity criterium which the author illustrates with examples [51] such as that neither a novel reinvented wheel nor a straightforward novel extension of an already existing patent would appear creative despite their usefulness and novelty with the former i.a. not being surprising and the latter not original. However, a refinement of this subjective three-factor definition of creativity has been recently provided by Tsao et al. [53] who associate creative outcome with perceived *utility* and *learning* whereby learning subsumes a blindness factor and importantly surprise. In order to unfold this definition, the next paragraph briefly expounds the contextual methodology the authors presuppose to assess a given idea in context. Thereby, the focus is not on a detailed mathematical elaboration, but specifically on the identification of core constituents relevant from an enhancement perspective for a future ACA endeavor.

By way of illustration, consider the following three time windows occurring *after* the idea generation: a pre-test phase, a test phase and a post-test phase. In the pre-test phase, a prior assessment in line with the best current knowledge is performed in which a probability distribution over the assumed utility of that idea is provided. (A reference is the routine expertise exhibited by *"persons having ordinary skill in the art"* [53].) In the test phase, the idea is deployed in the environment and observations of its consequences become available. In the post-test phase, a posterior assessment takes place via an adjustment of the probability distribution provided in the pre-test phase now that the idea was tested in the environment. Against this backdrop, the authors identify creative ideas as ideas which – as evaluated retrospectively after the post-test phase – simultaneously combine a high level of posterior utility, prior blindness (associated with the width of the distribution), and much more crucially than blindness, posterior surprise[1]. They denote this cluster of ideas as *"disconfirm disbelief"*[2], since it refers to ideas that were initially estimated to be relatively useless but which turned out to be highly utile with a subjective high certainty causing a reshaping of prior knowledge, a useful learning. In short, creative ideas exhibit *implausible utility* [53]. This underlying decomposition of creativity perception into a *utility* and a *learning* part, suggests the consideration of a motivational and an

[1] The reason being that in their formulation *"learning depends on the square of posterior surprise, but only on the logarithm of blindness reduction"*. Posterior surprise is the (normalized) absolute difference in mean utility between prior and posterior.

[2] An exemplary case mentioned by the authors is the theory on continental drift by Alfred Wegener which was initially disbelieved and underestimated.

epistemic[3] component respectively. Finally, note that the mentioned conscious evaluation of creative ideas in context is not restricted to test phases in real-world environments, but can also refer to imaginative settings at the personal level via thought trials at different temporal scales. This type of view makes the described evaluation also applicable to artistic contexts [51] where individuals might however use criteria for aesthetics from narrower social contexts.

1.2 Creative Process

In this connection, it is often one-sidedly assumed that "creative thinking" can be reduced to the notion of *divergent thinking* [27], a thought process involving unconventional associations and leading to a breadth of alternative solutions. Conversely, *convergent thinking* refers to thought processes selecting a unique appropriate solution to a problem with a single correct solution. However, creative processes include both divergent and convergent thinking [50] and are better described as processes of multifaceted nature [40]. For instance, Eysenck pointed out the illusory nature of this dichotomy and suggested considering a continuum between divergent and convergent thinking related to the *"relative steepness of the associative gradient"* [28]. To navigate a complex changing world, humans might need to dynamically switch positions along this continuum during tasks requiring creativity. Similarly, diverse functional connectivity studies [1,4,9,10,12,13,19,22,33] reveal a dynamic interplay between three multipurpose and domain-general functional brain networks in tasks involving creative process: the default mode network (e.g. medial prefrontal cortex, posterior cingulate cortex and hippocampus), the executive control network (e.g. dorsolateral prefrontal cortex and posterior parietal cortex) and the salience network (e.g. anterior cingulate cortex and anterior insula but also e.g. amygdala, ventral striatum, ventral tegmental area and substantia nigra). Thereby, during various creative tasks, the default mode network (DMN) can be linked to associative processes, the executive control network (ECN) to diverse executive processes, while the salience network (SN) associated with a type of affective attention regulation [2,13,41] facilitates i.a. a dynamic orchestration between DMN and ECN [12].

However, in order to make justice to the breadth of creative processes in the brain, it is essential to consider their peculiar evolutionary nature [25]. Crucially, in order to avoid misunderstandings, it is vital to note that the evolutionary account of creative process is not identical with Darwinian biological evolution. In fact, a first prototype of an evolutionary account for creativity was even advanced a few years *before* the publication of Darwin on "Origin of

[3] Abstractly speaking, this is reminiscent of curiosity in (en)active inference via (expected) free energy minimization decomposable into components of motivational value and epistemic value [31,32]. Future work could elucidate whether this explains why retrospectively contemplating creative ideas in context (as mental juxtaposition of pre-test phase, test phase and post-test phase underlying *"disconfirm disbeliefs"* events) is appealing and whether this reinforces future creative action.

Species" [17,51] by Alexander Bain. The main implication is that while Darwinian biological evolution is *blind* since it has no goal, creativity is aimed at something and includes an element akin to an abstract task goal [14,23] functioning as predictive fitness criterium. For this reason, *"there is agreement that human idea formation is directed to some degree"* [26] in modern creativity research. While there is no coupling between variation and selection in Darwinian biological evolution, creativity mostly implies a certain coupling of these components leading to the formulation of a *continuum of sightedness* marking the degree to which this is the case for a given creative process. (Certain researchers prefer to label this continuum as a blindness continuum [51], while some argue that a process can be either blind or sighted to a certain degree [44]. To put it very briefly, the blindness degree b is defined as $b = (1 - s)$ with s representing the sightedness degree [51,53] reducing the issue to a linguistic debate.[4]) Along this sightedness continuum, Dietrich distinguishes between the *deliberate mode*, the *spontaneous mode* and the *flow mode* [25]. We see the deliberate mode as consciously attended creative process allowing strong executive control but with constrained associative parts and the spontaneous mode as unconsciously progressing process with stronger associative components but much less executive engagement (such as during an incubation phase leading to sudden creative insights [8]). Thereby, the flow mode is an immersive largely unconscious[5] creative enactment in real time including automated motor skills (such as during spontaneous jazz improvisation). Obviously, the degree of sightedness is the highest in the deliberate mode, moderate in the spontaneous mode and zero in the flow mode – which however uniquely operates in the space of *already known* motor emulations [24].

Given the scarcity of theoretical frameworks integrating these threefold evolutionary view on creativity with the mentioned weighty empirical functional connectivity findings, we briefly introduce a simplified *tripartite evolutionary affective*[6] neurocognitive model of creative process (TEA). As suggested by Benedek [14], *idea generation* (for variation) consists of a *retrieval* and an *integration/simulation* phase. Prior to initial idea generation, a problem definition is required to establish a task goal acting as selection criterium. The retrieval phase identifies promising often only remotely related memories and the simulation/integration part supplies a novel recombination and assimilation of this material. This idea generation guided by the task goal can be followed by a forwarding (which we call an *affective redirection operation* (ARO)) to a stringent *idea evaluation* [42] involving a high-level assessment of the obtained results

[4] An exemplary evolutionary account of creativity is the so-called Blind Variation and Selective Retention (BVSR) theory. It has been suggested that instead of viewing BVSR as Darwinian, *"it is more conceptually precise to view both BVSR and Darwin's evolutionary theory as special cases of universal selection theory"* [51].

[5] Settings requiring further executive elements (beyond focused attention) and higher cognitive functions are not seen as flow (mode) experiences [21,24] but as deliberate.

[6] It integrates disparate tripartite and evolutionary elements from Dietrich's creativity framework [24], evolutionary aspects from Benedek's RISE model [15] and affective and procedural elements from the neurocognitive model by Kleinmitz et al. [42].

selected so far. However, an ARO can also alternatively re-initiate a further idea generation process or already trigger a response. The idea evaluation can either lead to a response, a further refinement of the idea generation process or an alteration of the task goal itself. Overall, the simplified neurocognitive TEA model to be refined in future work allows the following assignments. First, in the case of the deliberate mode, the idea generation can i.a. involve nodes of the DMN [42] to a more or less high degree whereby especially the integration/simulation is controlled by the ECN [14,15]. The subsequent (optional) stringent idea evaluation involves nodes of the ECN [14,42]. Second, in the spontaneous mode, the ECN is *not* strongly modulating DMN idea generation [10,27] and a stringent idea evaluation phase does not occur. In both modes, the SN related to affective attention conducts the dynamic AROs (see e.g. [13,39,42]). Third, the blind flow mode mainly implies emulations within the motor system [23,27]. Finally, note that a specific creative act can also connect multiple distinct creative modes [24].

2 Constructing ACA

2.1 Methods for Anthropic Creativity Augmentation

In the following, we collate a non-exhaustive heterogeneous set of selected indications which could if combined contribute to a certain extent to anthropic creativity augmentation. Thereby, it is important to note that useful combinations might vary e.g. given different psychological traits or socio-cultural contexts.

- ***Transformative Criticism and Contrariness:*** In order to foster the emergence of creative ideas exhibiting implausible utility in science, it has been suggested for knowledge gate keepers to encourage scientific knowledge paired with contrariness [53] – a trait linked with an idea generation process containing counterfactual divergences to mainstream ideas. Overall, it is straightforward to realize the importance of cultivating properties that reinforce the *"disconfirm disbelief"* pattern supporting the Popperian scientific process of conjectures and refutations e.g. for better task goals and idea evaluations within creative process or better test phases in creativity outcome in context. Moreover, a broad transdisciplinary education [3,36] might enhance associative elements. From an artistic perspective, it might include the transformation of the landscape of socio-material affordances [49] restructuring the human affective niche.
- ***Divergent Thinking Training:*** As mentioned earlier, divergent thinking only represents one aspect of creativity. However, the identification of multiple appropriate solutions can represent valuable domain-general elements for idea generation. For instance, a cognitive stimulation training [30] exposing subjects to ideas of other social entities prior to the idea generation phase (in the deliberate mode) improved divergent thinking and led to structural and functional changes within nodes of the ECN [52]. Moreover, a continuous involvement in divergent thinking tests of verbal creativity has been related to changes in brain functional connectivity with an enhancement of retrieval and integration processes [29].

- ***Alteration of Waking Consciousness:*** For creative insight of the sort rather associated with the spontaneous mode, a suitable strategy represents the relaxation of high-level prior beliefs [18] which might foster openness to experience, a key trait linked to cognitive flexibility and creativity [11]. Already the instructive cue to engage in creative thinking can yield a higher creative performance [34]. Another measure is to consciously shift creative problem solving to the spontaneous mode by trying to enforce an incubation period [8,37] whilst performing an undemanding distractive task. Beyond that, while brain activity has been shown to reside in a regime close to criticality between stability and flexibility [6] (at the edge of chaos [16]), a brain regime closer to criticality with an expanded repertoire of brain states seems achievable for healthy individuals with an appropriate intake of psychedelics [6,18,45,47]. Via the relaxation of high-level prior beliefs, a heightened sensitivity to the external and internal milieu [7] promoting a successful incubation phase is conceivable. Finally, certain meditative practices have been linked to improvement in divergent thinking tasks [20].
- ***Active Forgetting:*** There is a link between creative insight and fact-free learning [18] which refers to a type of learning in the absence of additional facts by restructuring already acquired knowledge e.g. by erasing redundant material. Such a complexity reduction [37] is actively performed in the brain during REM (rapid eye movement) sleep (with neurons in the hypothalamus interfering with memory consolidation in the hippocampus) which provides an explanation for the difficulty to maintain memories of dream contents [38]. REM sleep may thus not only be relevant for mental health and adaptive prospective aspects [46] but also for the incubation of novel spontaneous creative insights via unconscious complexity reduction mechanisms [32].
- ***Frequent Engagement:*** A trivial but perhaps underrated aspect of creativity is the observation that to a certain degree *"highly creative ideas are contingent on chance or "luck""* [51] with creative achievements among others also simply linked to a higher number of trials. While frequent practice represents a pre-condition for the flow mode to be attainable in the first place [23], the deliberate mode might be amenable to enhancement via exercise to a certain extent as reflected by the obtainment of neural plasticity in one of the mentioned divergent thinking training tasks [29].
- ***Brain Stimulation:*** Interesting for the flow mode is that excitatory transcranial direct current stimulation (tDCS) of the primary motor cortex during spontaneous music improvisation [5] yielded an enhancement of the musical performance. In the case of the deliberate mode and if unconventional associations are desirable, an inhibitory tDCS on the dorsolateral prefrontal cortex might at first sight appear suitable for a disruption of inhibitions by the ECN. However, such a measure is not recommendable for complex real-world applications [48]. Being a task requiring more executive control, deliberate analogical reasoning was enhanced via excitatory tDCS on the frontopolar cortex located within the frontoparietal network (or ECN) [35].
- ***Sensory Extension:*** A straightforward way to diversify associative processes, is certainly to augment the breadth of the actively sampled sensorium

e.g. via cyborgization and sensory extension measures. From an artistic angle, it is for instance easy to imagine that various augmented sensorimotor and affective synaesthetic could support the incubation phase in the spontaneous mode next to conferring a finer granularity to perception. Further conceivable transformative sensory augmentations that could foster creative associations represent virtual reality frameworks [2] and perhaps "dream engineering" methods including lucid dreaming as a state with intermediate hypofrontality [37] having certain neurophenomenological resemblances with psychedelic-induced states [43].

2.2 Addressing the Augmentation of Artificial Creativity

One can assume that artificial creativity exists in a primitive form when it comes to an artificial creative process with a very high degree of sightedness [23] (e.g. dictated by high-level anthropic utility functions). Indeed, when the consideration of the creative agent is not included in the perception of creative outcome, the substrate on which the forgoing process occurred seems irrelevant. However, when considering the entire action-perception sequence of most anthropic creative acts (as a juxtaposition of creative process, pre-test, test and post-test phase – all permeated by affect e.g. via AROs and utility assignments) which can even take place within the imagination of the same anthropic social entity, a certain gap between AI and human entities becomes apparent. Therefore, firstly, a figurative *immersion in the human affective niche* might be necessitated for contemporary AI such that its outcomes in context *can* better correspond to samples that matter to humans in the first place. Exemplary early steps could include multimodal experiential data for AI and also the encoding of affective and socially relevant parameters into AI goal functions [3] in addition to straightforward parameters directly related to the creative tasks in question. A next step could be to transfer a main anthropic affective concern to AI which is an affinity to curiosity that manifests itself via an active sampling of the world [32]. Secondly, equipping AI with *social cognition* abilities might be helpful, since *"imagination is the seed of creativity"* [33] with imaginary perspective-taking having inherently social dimensions. It is no coincidence that the domain-general DMN dominating highly associative spontaneous idea generation is also involved in the construction of e.g. social affiliation, moral judgements, empathy, theory of mind [41] as well as mental time travel and counterfactual thinking [18]. Thirdly, when considering that both anthropic waking perception and imagination are linked to an egocentric virtual reality experience [37,54] (with waking perception being constrained by reality), one might naively deduce that a full immersion of AI into the *human* affective niche necessitates at least that: an *egocentric integrated multimodal virtual reality experience* of the world. However, this also raises the questions on whether to then call it "human" would not be anthropocentric and whether this reveals a tradeoff between AI creativity and AI controllability.

3 Conclusion

By espousing both the augmentation of anthropic and the augmentation of artificial creativity, the motivated ACA research could connect disparate existing subfields under one *substrate-independent goal*: namely a scientifically grounded augmentation of knowledge creation (which can encompass science, culture, arts and technology) to indirectly tackle societal challenges. Creativity represents an essential transformative element of human knowledge advancement for adaptive purposes in relatively fast changing environments [53]. Hence, ACA could indirectly serve the need to identify requisite variety at the right time as proactive and corrective defense method in the light of current global socio-ecological and socio-technological challenges [3]. In this paper, we compiled recent research on anthropic creative outcome in context and findings on creative process which we extended with a simplified neurocognitive *tripartite evolutionary affective* model of creative process (TEA). Building on this analysis yielding a scientific grounding for ACA, we identified seven potential high-level indications to enhance anthropic creativity: *transformative criticism and contrariness*, *divergent thinking training*, *alteration of waking consciousness*, *active forgetting*, *frequent engagement*, *brain stimulation* as well as *sensory extension*. Finally, we suggested three synergetic aspects as possible indirect support for artificial creativity: *immersion in the human affective niche*, *social cognition* and an *egocentric integrated multimodal virtual reality experience* of the world. Future work could refine the TEA model, augment the tenfold methodology for ACA and address open questions.

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