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Cultivating an understanding of curiosity as a seed for creativity

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Curiosity—the desire to know—is a powerful motivator for learning and behavior. Theoretical and anecdotal discussions have also linked curiosity to creativity and innovation, but there is little empirical evidence for this connection, aside from a handful of recent studies. We review the existing evidence and discuss potential mechanisms through which curiosity may facilitate the creative process. We further discuss important methodological issues that have limited past research on the relationship between curiosity and creativity. One limitation is the lack of studies investigating curiosity as a psychological state that fluctuates over time and with changing contexts rather than only as a trait. Another limitation is the scarcity of behavioral measures of exploration and curiosity. We discuss the few existing behavioral measures that have been used and introduce a new measure relying on real effort.

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> I have no special talent. I am only passionately curious.
> —Albert Einstein, from Letter to Carl Seelig, 1952.

Curiosity—the desire to know—is a powerful motivator for learning. The wealth of positive life outcomes associated with this trait has inspired news outlets to herald it as a 'superpower', a seductive enabler of innovation. But despite a long history of research on curiosity, much is still unknown about it. One question in particularly dire need of further research concerns the association between curiosity and creativity.

We begin this review by highlighting the limited existing research examining the relationship between curiosity and creativity, as well as possible shared mechanisms that may drive the relationship between these two characteristics. We end this section by highlighting important methodological issues currently limiting progress in understanding this connection. In particular, we note the largely correlational nature of existing research which relies almost entirely on self-report, trail-level questionnaires.

In the following two sections, we call attention to the fact that curiosity, while varying across individuals, also fluctuates within individuals. We suggest that future experimental research should examine the consequences of states of curiosity on creativity; however, we note that such research requires reliable behavioral measures that capture momentary states of curiosity, which are currently lacking. To this end, we propose a novel effort-based behavioral measure. We conclude this review by noting several intriguing directions for future research.

The relationship between curiosity and creativity

Curiosity involves the pursuit of new knowledge and experiences. Creativity involves transforming existing knowledge, ideas, or objects into something novel and interesting. When framed in this way, it is easy to see the overlap between the two—both revolve around novelty. But is this a superficial similarity, or are curiosity and creativity tied to one another in a fundamental way?

A number of recent studies have begun to address this question. First, individual differences in curiosity have been linked to people's perceptions of themselves as creative [1•,2,3•], as well as predicting entrepreneurial and workplace innovation [4–6]. A recent study investigating individual differences in exploratory eye movements also found correlations between curiosity and creativity [7••]. In this study, two types of curiosity were examined: Epistemic Curiosity [8], or the desire for knowledge, and Perceptual Curiosity [9], an interest in novel sensory experiences. Both types of curiosity were correlated with self-reported creative behaviors (e.g. making crafts or painting), creative personality characteristics, and performance on a creative drawing task. Interestingly, the strength of the correlations was similar for perceptual and epistemic curiosity, indicating that both the more intellectually oriented curiosity as well as the desire for new sensory experiences may be important for creativity.

It has been argued that a sense of curiosity is a necessary, though not sufficient, condition for creativity [10] in that curiosity may facilitate the desire to engage in creative behaviors. In line with this reasoning, a recent study found that curious individuals ask more open-ended questions to feedback providers while working on a creative design task, which in turn enhanced the quality of their creative designs [11]. Curiosity has also recently been found to impact the generation stage of the creative process [12••]. In this investigation, epistemic curiosity was again examined, and the study further distinguished between its two subcomponents; diversive curiosity, also referred to as interest curiosity, which is characterized by a broad interest in new information; and specific curiosity, also referred to as deprivation curiosity, which is characterized by a desire to gain knowledge about a particular topic in order to fill a knowledge gap [13,14]. It was found that diversive, but not specific, curiosity predicted creative problem solving. This effect was mediated by information seeking in the early stages of the creative process.

Specific curiosity, in contrast, may benefit creativity when specific expertise is required. When looking for a creative solution for lowering carbon emissions, for instance, one might benefit from an intrinsic desire to learn everything there is to know about carbon emissions. In line with this reasoning, a recent investigation found that specific curiosity promotes creative thinking via *idea linking*, a sequential process of exploration by which information on a specific topic initiates a cascade of ideation that eventually leads to a solution [15••].

What can this recent work tell us about the mechanisms linking creativity and curiosity? The studies reviewed thus far speak to several mechanisms through which curiosity can facilitate creativity. These include basic exploratory tendencies (i.e. exploratory eye movements) and more complex information seeking behaviors (i.e. asking questions, linking ideas). Creative cognition is now also widely thought to involve attentional mechanisms [e.g. Refs. 16,17], specifically, an inability to filter irrelevant information. Curiosity similarly is characterized by a wide scope of attention, as indicated by neuroscientific and eye tracking studies [18–20,7••]. Thus, in addition to exploration and information seeking behaviors, a wide scope of attention may be another mechanism through which curiosity facilitates the creative process. Moreover, zooming out to a more temporally extended level of analysis, an individual's perpetual desire to acquire knowledge may lead them to deeply engage with unfamiliar ideas for sustained periods of time. This sustained engagement may help them discover something original or bring about a substantial body of creative work.

It should be noted that empirical evidence to support the creativity-curiosity connection is still very scarce. The aforementioned correlational designs are only suggestive of a causal relationship. To date, very few studies have experimentally manipulated curiosity to look for causal effects. In a recent meta-analysis gauging the strength of the relationship between curiosity and creativity, the included studies were all correlational and relied on self-reported trait measures of curiosity [32••]. Indeed, one issue that currently limits curiosity research is the lack of studies—particularly studies using behavioral measures—that assess curiosity as a psychological state rather than only as a trait.

Curiosity as a psychological state

Most definitions of curiosity describe it in an inherently dynamic way, as a 'desire' or 'motivation' rising and declining depending on context, comparable to physical hunger [33]. We are in a constant flux between seeking and satisfaction [34]. It is therefore peculiar that empirical research has almost exclusively operationalized curiosity either as a stable trait or as the product of inherent qualities (e.g. novelty, complexity or perceptual ambiguity) that make a stimulus interesting to most people [35,36,33,37–39]. While some individuals are generally more curious than others [40], and some stimuli generally more curiosity eliciting than others, it also seems clear that a topic can fail to capture our interest one day, yet send us down the proverbial rabbit hole the next. This may have more to do with the cognitive processes going on in the moment [41] than with the qualities of the stimulus or our personality characteristics. Yet, rarely has curiosity been studied as a state that differs not only between individuals but also from one moment to the next [see Refs. 42,34].

A handful of studies examining how curiosity can be evoked stick out as exceptions. Even though curiosity is generally theorized to be an *intrinsic* motivation, studies have found that framing a topic as having practical value (e.g. being relevant to 'important scientific and medical breakthroughs') makes people more curious about the topic than introducing the topic matter-of-factly [43]. Similarly, people are more curious about questions that are deemed more interesting by others [44]. However, it remains unclear whether such cues of value trigger only superficial curiosity or translate to deep, sustained interest in a topic.

Other research has examined how engaging with information by making guesses affects curiosity. In one set of studies, participants were shown obscure words (e.g. hispid) and asked how curious they were to learn their meaning [45]. Participants were more curious when they were asked to guess the meaning of the words before seeing the answer. In another study, participants were shown trivia type questions (e.g. 'x out of 10 animals are insects') and were asked to either generate a relevant fact about the topic (e.g. 'ants are insects') or guess the answer [46••]; guessing increased curiosity. One explanation for

the results is that making a guess requires effort and deep engagement with the content, which in turn may increase curiosity. Alternatively, making a guess may evoke curiosity because it motivates people to confirm whether they were correct [41].

The few studies that have attempted to experimentally induce curiosity, though promising, leave big questions unanswered. For instance, once curiosity is triggered by a cue, a question, or a guess, might it carry over to another topic? Does asking questions or making guesses lead to deep and sustained curiosity? And does the effectiveness of such manipulations depend on moderating factors, such as a person's expectations, the perceived cost associated with exploring information, or a person's Openness to Experience, need for closure or need for autonomy [see Refs. 34,31]? And most critical to the present discussion, do manipulations that increase curiosity subsequently impact creativity? Finding the answers to these questions will not only be valuable for our scientific understanding of curiosity, but will be essential for interventions aiming to boost curiosity for the benefit of learning and creativity. Indeed, to the best of our knowledge, despite the highly suggestive relationship between curiosity and creativity, to date, only one published study has specifically demonstrated an experimental link between induced states of curiosity and creativity [15••].

Assessing curiosity through behavior

As we take the next step toward experimental interventions to boost curiosity, we will need to rely more strongly on behavioral measures in addition to the usual self-report measures, which raise issues of expectations and social desirability. Thus far, this is the rare exception. A meta-analysis of studies examining curiosity within educational settings found that over 90% of the reviewed studies used self-report measures. Aside from self-reports, neurobiological and behavioral measures such as fMRI, pupil dilation or exploratory eye movements have occasionally been used to indicate curiosity [e.g. Refs. 46••,7••,37,33]. Furthermore, in at least one study, these indices have been related to creativity. Specifically, Gross *et al.* [7••] observed that exploratory eye movements were associated with performance on a creative drawing task. However, measures such as exploratory eye movements are indirect and can also be driven by salience attribution processes not necessarily related to curiosity.

One behavioral curiosity measure that has been used in several studies is a person's willingness to pay points or money in exchange for information [e.g. Refs. 47,48••,37]. The elegance of measuring curiosity with willingness to pay is that it is directly aligned with the definition of curiosity as the desire to acquire information. Research using this measure has shown that people are willing to pay for information even when doing so does not have any instrumental value other than satisfying a person's curiosity [47,48••]. A similar behavioral measure, likewise based on the idea that curious individuals are willing to incur a cost in exchange for information, is willingness to wait [10,49].

Other recent research has looked at people's styles of information-seeking by analyzing the contents of Wikipedia entries participants explored in over 5 hours of browsing [50]. The research found that individuals higher in specific curiosity were more likely to explore a small selection of tightly related content, whereas participants higher in diversive curiosity were more likely to browse loosely connected content. The strength of this approach lies in the ecological validity of observing intrinsically motivated and spontaneous exploratory behavior in a naturalistic context. However, the method is time intensive, and it is not clear to what extent it taps into differences in trait curiosity or can capture the ebb and flow of a person's momentary curiosity.

Recently, we have developed another behavioral measure adapted from economics research [51,52]—an effort task in which participants can 'work' for information. This work consists of moving sliders to target positions. The task is effortful and time intensive, but self-paced and extremely simple. Therefore, an argument can be made that it captures a person's willingness to exert effort for information, independent of specific skills. A potential advantage of using effort over monetary cost is that it mimics ways of satisfying one's curiosity in real life. Acquiring knowledge usually requires effort, but rarely do we directly exchange points or money for knowledge. Our research has shown that participants exert more effort for answers to trivia questions that they previously had not been able to solve. We also found that effort in exchange for answers to questions was predicted by self-reported curiosity for those questions, and effort in exchange for solutions to the problem of plastic waste was predicted by self-reported concern for the environment. Effort on the task also correlates with trait curiosity, though to a lesser extent. Thus, the task is a good candidate measure for future studies assessing the effects of experimental manipulations of curiosity.

Several questions remain to be explored. To what extent do effort-based measures overlap with or have (dis)advantages compared to self-reports and willingness to pay or wait? One potential benefit of using effort over self-reports or willingness to pay is that a self-report or payment in exchange for information provides only a snapshot of an individual's curiosity at one time. Effort is more dynamic. A given person may initially invest high effort into obtaining information but quickly lose motivation and give up. Another person may persist in exerting effort over a long stretch of time. Both individuals might have named the same high price if asked how much they are willing to pay for the information, but the first

person exhibits less curiosity in their behavior over time compared to the second person. This dynamic aspect also makes the effort task more closely resemble real-life behavior, which is typically extended in time. Only willingness to wait is a similarly dynamic measure. However, willingness to wait may be more difficult to experimentally control compared to an external task like the effort task, because the subjective cost of waiting may depend in part on what is going on in a person's mind. Waiting may feel less costly to a person who is engaged in an interesting daydream [53]. In this case, a greater willingness to wait may not necessarily reflect eagerness to get information, it may simply reflect greater tolerance toward waiting. Thus far, however, these arguments remain speculative, and future research should directly compare real effort to self-reports, willingness to pay, and willingness to wait.

Another open question is how effort tasks can be designed to distinguish different types of curiosity. Depending on the type of information participants 'work for', might versions of the task be suitable to capture the aversive state associated with specific (or deprivation) curiosity or the appetitive state associated with diversive (or interest) curiosity? In our studies, effort tended to be more strongly associated with diversive than with specific curiosity. However, in our studies, participants worked for a chance to satisfy their intrinsic curiosity about a broad topic (i.e. ways to protect the environment). Different results may emerge when individuals work for answers to trivia questions or answers that have more instrumental value for solving a very specific personal problem. Further research into these design considerations is needed along with experimental manipulations that evoke the different types of curiosity.

Concluding remarks and future directions

Many theoretical discussions have linked curiosity to creativity and innovation, but empirical evidence directly supporting this link is currently extremely scarce. Although research on each respective construct indicates mechanistic links, more research is necessary to determine how different aspects of these two constructs are related. Are perceptual and epistemic curiosity underscored by the same attentional and motivational processes? Are these same processes linked with visual and verbal creativity, or Scientific and artistic creativity? Future investigations should aim to determine the overlap between the processes that underlie the many facets of these two incredibly broad and multi-dimensional constructs.

This review largely focused on epistemic curiosity; however other types of curiosity exist. Kashdan *et al.* [21] identified at least five distinct factors of curiosity. Two map onto epistemic curiosity (deprivation sensitivity and joyous exploration); additionally, social curiosity, thrill seeking, and stress tolerance were revealed as distinct types of curiosity. These types may be relevant for creativity, yet they have almost never been examined in that context. For example, stress tolerance—the ability to handle the distress or anxiety inherent in novel experiences—may be relevant to creativity. In the real world, creative endeavors are often risky, thus an ability to handle the stress of creative pursuits could be important.

The current lack of experimental research leaves open many other possible pathways for linking curiosity and creativity. One important consideration is the role curiosity may play in the relationship between other personality traits and creativity, most notably Openness to Experience. There is abundant evidence linking Openness to creativity [22–25]. Most measures of Openness have subdimensions that map onto curiosity; the NEO PI–3 ideas dimension [26], the BFAS intellect dimension [27], Woo's curiosity dimension [28], and the HEXACO inquisitiveness dimension [29]. Future research is necessary to determine whether the relationship between Openness and creativity is driven especially by its curiosity related subdimensions. Similarly, boredom proneness has been found to predict both creativity and curiosity [30], while flow states have also been suggested to connect curiosity to creativity [31]. Measures such as these should be included in future research to tease out the active ingredients that may drive this relationship.

Our understanding of the curiosity–creativity relationship is limited, and there are many intriguing future directions for examining this topic. However, such research is hampered by methodological limitations, particularly the scarcity of state and behavioral measures, as well as experimental manipulations evoking states of curiosity. Initial evidence relating epistemic and perceptual curiosity to creative behavior and performance largely relies on correlational designs. Therefore, we do not know conclusively whether curiosity is really a cause of curiosity, or whether engagement in creative acts may lead to curiosity, or whether curiosity is linked to creativity through some other factor(s). Future experimental research exploring how or even whether it is possible to promote creativity via curiosity will surely open up many more fruitful avenues for research and further our understanding of how to harness the benefits of curiosity.

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Conflict of interest statement

Nothing declared.

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Papers of particular interest, published within the period of review, have been highlighted as:

• of special interest
•• of outstanding interest

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