**Attention, Technology, and Creativity**

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Imagine a scientist who is working on an experiment—reading articles and jotting down notes for the framework—when she reaches an impasse. She realizes that one part of the experiment won’t work and she backs her chair away from the desk, frustrated, deciding to take a break. She scrolls through Twitter on her phone, seeing posts from her friends and colleagues—some professional, some less so. She walks to the kitchen and looks out the window as she pours herself a glass of water, watching tree branches sway in the wind. As she walks back to her office she has an idea on how to move forward—a creative insight. Did her break contribute to this insight? Did her use of Twitter? In this essay we use findings from psychology and neuroscience to help determine the impact of recent digital technologies—such as smartphones, social media, and online games—on attention and creativity.

# **A primer on the scientific concepts of attention and creativity**

Attention is one of the most basic mental functions. In the brain it allows for the selection of preferred neural signals by increasing their strength through neural feedback, thus diminishing the relative strength of other neural signals. It is attention that allows the scientist, for example, to focus on her experiment design while people chat nearby, since her own thoughts are highlighted at the expense of those conversations.

Attention comes in many forms. Most relevant to this essay is the difference between “top-down” and “bottom-up” attention. These concepts are based on a much older division between voluntary and non-voluntary attention. This is the difference between using attention to further a goal or interest—such as working on an experiment—and one’s attention being occupied by a distracting stimulus—such as people chatting nearby.

The difference between voluntary and involuntary attention is measured in behavior through “endogenous” and “exogenous” cues.[[1]](#footnote-1) Whereas endogenous cues are symbolic and direct attention to a target (e.g. an arrow), exogenous cues are salient and capture attention at the location of the target (e.g. a flash). Exploring this difference with brain imaging allowed researchers to separate the brain networks responsible for top-down attention, associated with endogenous cues, from those responsible for bottom-up attention, associated with exogenous cues.

Importantly, these top-down and bottom-up networks are part of a larger system of attention.[[2]](#footnote-2) One can envision this as a system of resource distribution, with top-down attention favoring one’s current goals and bottom-up attention favoring salient stimuli, with one’s focus landing on one or the other depending on the strength of each.

Top-down attention is key to mental control and autonomy, or the ability to act in accordance with one’s own interests and values. Whereas bottom-up attention occurs for salient stimuli, top-down attention occurs when one’s current task is maintained despite those stimuli. Mental control and autonomy are based in this ability to exert control over mental resources, and this is just what some are concerned is under threat from the use of recent digital technologies.

A separate issue that is often brought up in discussions of these technologies is creativity, and whether it is helped or hindered by their use. Creativity requires both novelty and utility: “There is a broad consensus that creativity is the capacity to produce things that are original and valuable.”[[3]](#footnote-3) Both of these conditions (novelty/originality and utility/value) can be satisfied at either the subjective or the objective level, and need not be associated with monetary or other social gains. The creative insight of the scientist might be novel to her but not to others; a new scientific hypothesis could be useful because it furthers understanding for the scientist or for the field at large. Ruled out are cases of useless novelty, such as gluing a hammer to a nail.

Psychologists have found that creative ideas are formed through a dual process of generation and evaluation.[[4]](#footnote-4) During the generation process many ideas are explored, while during the evaluation process the ideas are assessed and further elaborated, leading to the selection of the most novel and useful ideas. The scientist, for example, might first explore the space of possible solutions and then apply them to determine the optimal solution. Thus, the brain does not include a specialized area for creative cognition: creativity arises from interactions between multiple cognitive mechanisms such as memory and executive function.

Attention and creativity may at first seem opposed to one another—attention is associated with control and constraint, whereas creativity is associated with novelty and growth. Yet, the connection between them is more complex. Some argue that creativity occurs in the absence of attention, but others argue that different forms or styles of attention contribute to different forms of creativity.[[5]](#footnote-5) We argue, instead, that the condition of utility, engendered by the evaluation phase of creativity, requires a role for attention. Thus, if recent digital technologies reduce our capacity for attention, they are likely to also negatively impact our creativity. We will come back to these issues after we first examine the evidence that recent digital technologies undermine top-down attention.

# **The impact of recent digital technologies on attention**

Recent digital technologies target attention. As we discuss in more detail below, they have beendesigned to manipulate attention, in the sense of covertly capturing and engaging it; they are interactive at very short time intervals, increasing their ability to capture attention; and they are adaptive, in the sense that they can easily adjust in order to better manipulate attention. These facts are concerning given the link between attention and autonomy described above: “we may justifiably worry about whether social media are undermining our ability to shape our own lives by making us less able to focus on our goals and more likely to chase after immediate diversions.”[[6]](#footnote-6) Indeed, in our review of the evidence it appears that recent digital technologies have a lasting impact on our ability to control attention in a top-down manner, and thus on our autonomy.

1. **Common design elements of recent digital technologies**

A common design element that is used to manipulate attention in recent digital technologies is *intermittent variable rewards*, developed following their use in slot machines.[[7]](#footnote-7) These are rewards that vary both in rate (how often they occur) and magnitude (how large they are). The purpose of intermittent variable rewards is to keep the user’s attention on the product, since they cannot predict when they will receive the reward and how valuable the reward will be. Social feedback is naturally intermittent and variable, but this effect is amplified by social media when it, for example, adjusts the timing of notifications received by the user so that they arrive in less predictable batches. This and other techniques are used to capture the user’s attention at the expense of other activities without the user’s explicit awareness.[[8]](#footnote-8)

While many technologies have used intermittent variable rewards, recent digital technologies are more interactive than earlier technologies, making them much more successful at capturing attention. Take the difference between watching an advertisement on your television and smartphone—your attention may be captured by each, but only in the latter case does the advertisement change as a result of your attention (e.g. hovers and clicks). If you tap an advertisement on your smartphone, for example, you will likely be led to more information about the product being advertised.

What’s more, the scale of interaction is much greater than for earlier technologies: interaction occurs with a far greater quantity of information, individuals, and the corresponding spatial coverage than older technologies, given a fixed period of time. This makes the interaction more salient than one that involves less information, fewer individuals, or a smaller spatial region. At the same time, the interaction is much faster, with near immediate feedback to the user. Immediacy is important because even somewhat delayed feedback requires greater cognitive resources, making continued interaction less likely.

Finally, recent digital technologies are adaptive. They adjust to the clicking and hovering behavior of a user, and even the user’s personality and mood. This makes these technologies particularly well suited to manipulating our attention, sometimes using our vulnerabilities against us.[[9]](#footnote-9)

1. **The measurable impact of recent digital technologies on attention**

Given the design features reviewed above, one might wonder the extent to which recent digital technologies are *effective* at manipulating attention. They might be considered effective at manipulating attention, for example, if they captured attention against the wishes of the user, or at least against the better judgement of the user. Take, for example, the off-task use of smartphones by students in the classroom. It has been demonstrated that such usage of smartphones has a negative impact on academic performance, and yet this behavior is widespread. Assuming the student’s better judgment would be to abstain from using smartphones in the classroom, this appears to be evidence that they capture student attention against their better judgment.

Is this evidence of short or long-term impact on attention? It could be both. If we take a short-term perspective we treat the student’s self-control as fixed, and thus a confounding factor (i.e. low self-control causes both smartphone use in the classroom and lower grades). In one study that takes this perspective, accounting for personal and course characteristics revealed a reduced effect of smartphone use on grades.[[10]](#footnote-10) Yet, if we take a long-term perspective self-control may not be a confounding factor, since it might have been reduced by previous smartphone use.

A recent review finds good evidence that recent digital technologies harm attention in the short term, but limited evidence for longer-term impact.[[11]](#footnote-11) As an example of a short-term effect on attention, they describe a study in which mere exposure to notifications detracted from performance in an ongoing task. To explore the long-term effect, the authors examine studies on media multitasking, which look at the correspondence between the level of media multitasking in an individual (e.g. how often the individual looks at their phone while watching television) and that individual’s ability to direct and control their attention. A more recent review of media multitasking reports that “most studies to date report negative effects of media multitasking on measures of attention,” citing both brain and behavioral impacts.[[12]](#footnote-12) Yet, they also admit that it is difficult to tell whether the reduced ability to sustain goal-directed attention is caused by the multitasking or a pre-existing trait.

While the direct evidence for long-term impact on attention is limited, it is supported by evidence on addiction. Recall that recent digital technologies can be considered effective at manipulating attention if they capture attention against the wishes of the user—the hallmark of addiction. Addiction to recent digital technologies has become about as prevalent as alcohol addiction in the United States, with smartphone addiction seemingly replacing drug and alcohol addiction in younger generations.[[13]](#footnote-13) While this extreme case of long-term impact is limited to a subset of the population, it is reasonable to suppose that the long-term impacts on attention experienced by this group are shared to a lesser degree by other users. That is, those with Internet Addiction Disorder may be *unable* to control their use of recent digital technologies, whereas others are simply *less able* to control it.

Given the above evidence, we think there is reason to suppose that recent digital technologies have a long-term negative impact on our ability to direct and control attention. Our basic reasoning is as follows:

1. The use of recent digital technologies has a demonstrated short-term negative effect on one’s ability to sustain attention.
2. Brain plasticity allows the short-term effects of an activity to translate to long-term tendencies.
3. Both brain and behavioral differences in attention have been demonstrated in those who frequently use recent digital technologies, in keeping with 1 and 2.

In support of the first point is the evidence that recent digital technologies make it difficult to sustain attention on a chosen task, harming task performance. Our explanation for this is that bottom-up attention is temporarily prioritized over top-down attention, such that salient stimuli are prioritized over longer-term interests and goals. We discuss this further in the next section.

Other authors have argued for the second point: “The assumption of long-term effects of smartphone usage on cognitive functions based on findings from related fields...and the knowledge that brain structures can be altered with prolonged exposure to novel environments.”[[14]](#footnote-14) In other words, we know that changes to brain and behavior in the short term can translate to long term changes for extended use, and so it is reasonable to suppose that the short-term effects of recent digital technologies on attention that have already been established will be found to be at least a partial source of the brain and behavioral differences discovered in those who tend to use such technologies. Namely, the reduced capacity for sustaining attention to a current goal or interest in the face of distractions. Of course, this may not happen in all cases; one’s brain and behavior may adjust to or overcome the impact of these technologies, perhaps even using them for our betterment. Yet, it is our contention that this is not the norm, given the evidence provided above.

1. **The nature of the impact of recent digital technologies on attention**

Assuming that recent digital technologies have an impact on attention, what is the nature of that impact? There appear to be at least two effects relevant to our purposes: making the technology in question more likely to capture bottom-up attention and making top-down attention less effective.

On the first effect, we have already seen how recent digital technologies make themselves more likely to capture bottom-up attention—they use methods that make the use of these technologies seem more valuable to the user. We call this “artificial salience.” Recall, for instance, the use of intermittent variable rewards, known to cause addictive behavior in the user. Another common feature of recent digital technologies is to enable social connection and feedback, one of our greatest motivators. Combining the two is a very powerful recipe for capturing attention.

As to the second effect, this occurs when recent digital technologies bias the user to favor bottom-up attention in the long term. We call this “exploration bias.” One might think of the balance between top-down and bottom-up attention as favoring top-down attention when it is important to persist in tasks and bottom-up attention when it is important to continue to explore alternatives. Bermúdez describes how recent digital technologies push us to favor the latter: “the Internet enables us to process more things, but it simultaneously spreads our attention much more thinly to cover a wider area of content, and makes it continuously shift between tasks.”[[15]](#footnote-15) That is, by offering such a wide array of attractive options these technologies shift our attentional *strategy* in favor of exploration. We believe that over time this will move from a strategy to a trait, making the user less ableto exert top-down attention in a sustained manner.

Given all of this, is the effect of recent digital technologies on attention good or bad? The answer to this question isn’t obvious.

We do find artificial salience to be pernicious, at least in some cases. That is, the effect is associated with addiction in a subset of the population, meaning that these users no longer have control over their behavior with respect to these technologies. This loss of autonomy seems straightforwardly bad, just as in Alcohol Use Disorder.

Some have argued that the effect is also bad for the rest of the population: “By deliberately and covertly engineering our choice environments to steer our decision-making, online manipulation threatens our competency to deliberate about our options, form intentions about them, and act on the basis of those intentions...Online manipulation thus harms us.”[[16]](#footnote-16) That is, insofar as these technologies are purposefully undermining the user’sability to choose to occupy their time in another way, and without the user’s awareness, they are a threat to autonomy. In our view, much of the badness in this more general case will depend on the extent to which these efforts are both deliberate and covert.

We are more equivocal about exploration bias. One might worry about the loss of top-down control in this case. That is, in altering the balance between top-down and bottom-up attention, recent digital technologies may be seen as threatening our ability to exert top-down control, and thus as threatening our autonomy. Yet, top-down control is never total, and for good reason. Being responsive to changes in our environment is important, and sometimes more important than being able to persist in the task at hand. If our environment changed to one in which reactivity was more valuable than persistence, then it would be a good thing if our attention adapted to that environment.

What’s more, exploration bias may be conducive to greater creativity. It is often claimed in the popular press that recent digital technologies improve creativity due to a larger quantity of input: “The fact that everyone has access to a wealth and diversity of ideas and the means to actualize intent means that we all can be more creative.”[[17]](#footnote-17) If this is right, being more receptive to such input may enable even greater creativity. Yet, studies on the connection between recent digital technologies and creativity provide mixed evidence.[[18]](#footnote-18) In the next section we explore the connection between attention and creativity to better determine an answer to this question.

# **The dependence of creativity on attention**

As described above, creativity is a “bi-phasic” phenomenon, with one phase involving idea generation and another idea evaluation. Idea generation benefits from fewer constraints; that is, reduced top-down attention. On the other hand, the evaluation phase relies on increased top-down attention to assess the ideas and then to select and further elaborate the most appropriate ones, depending on the individual’s goals and interests.[[19]](#footnote-19) For example, the scientist trying to solve a difficult problem engages both top-down and bottom-up attention to do so: she allows ideas to percolate up through bottom-up attention and exerts top-down attention to help constrain the ideas (as well as, perhaps, to inhibit irrelevant sensory stimuli). Of course, the extent of the contribution of top-down and bottom-up attention depends on the type, context, and specifics of the creative activity.

Creativity is thus instantiated by leveraging both top-down and bottom-up attention. Neuroimaging studies of creativity corroborate this account. Creative cognition is supported by two large-scale brain networks—the default mode network (DMN) and the frontoparietal control network (FPN). The DMN is activated during episodic memory retrieval, self-reflection, thinking about the past, and planning for the future. The FPN is responsible for cognitive control and decision-making processes. The coupling of these two networks induces a unique state where memory retrieval and imagination continue in the absence of irrelevant sensory stimuli while, simultaneously, the self-generated mental content is guided and constrained by top-down regulation to fulfill a goal. This coupling is unique since the DMN and FPN are typically characterized as opposing networks; that is, the activation of one suppresses the activation of the other.[[20]](#footnote-20)

As we have described, creative cognition occurs when these two major networks cooperate, supporting both idea generation (through DMN and bottom-up attention) and evaluation (through FPN and top-down attention). Interestingly, a similar neural pattern is reported during certain mind-wandering episodes.[[21]](#footnote-21) Many studies have found that mind-wandering enables creativity, particularly when an individual hits an impasse while working on a problem. During mind-wandering the mind may be allowed to gravitate towards the unsolved problem, revisiting and exploring it with fewer constraints and from new angles.[[22]](#footnote-22)

Yet, while mind wandering is often associated with the absence of constraint, to enable creativity the cognitive process must involve some degree of control and constraint. This is because creativity requires not only novelty but utility, as defined above. Thus, creativity requires top-down attention. In our view the reason that creative cognition is associated with increased coupling between FPN and DMN is because creativity benefits from a closer connection between its two phases, with top-down attention playing a crucial role throughout the creative process.

Let’s return to the example at the start: recall that our scientist resolves an impasse after a break that involves both scrolling through Twitter and looking at the trees outside. We asked: Did her break contribute to this insight? Did her use of Twitter? We are now in a better position to answer these questions. On the first: since the type of thinking associated with creative cognition is unique, requiring the cooperation of brain networks that are typically opposed to one another, a break may be a good way to move into a state of creative cognition. On the second: while external stimuli may help to trigger a creative idea, the cognitive state induced by use of social media is generally opposed to creativity, since it puts pressure on top-down attention and control. Looking at trees, on the other hand, has been widely cited as restoring attention during a break, and so may serve as a better source of creative insight.[[23]](#footnote-23)

# **Conclusion and Future Directions**

We have established that disruptions of top-down attention are detrimental to creative cognition. Flurries of goal-irrelevant external stimuli designed to actively engage the user—flashing colors, noises, notifications, infinite scrolling—are likely to impede top-down attention, and thus creative problem solving. As we mentioned above, it seems unlikely that Twitter helped the scientist generate her creative insight; more likely is that the active and demanding nature of external stimuli originating from the Twitter app would break her chain of thought and distract her from the problem she is working on. However, not all external stimuli are equally active and demanding. When the scientist looks out the window or grabs a glass of water, she is interacting with external stimuli, but those stimuli are passive, and so need not interfere with top-down and goal-oriented processing in the background.

We find it unlikely that recent digital technologies typically foster creativity through changes to attention. While one hypothesis about creative cognition links it to reduced cognitive control, we have shown that the full story is much more complicated: reduced cognitive control may increase the number of ideas that one is presented with but it keeps one from effectively making use of those ideas. Creativity relies on a balance between top-down and bottom-up attention. This allows for goal-directed memory retrieval, generation of new mental representations, and then further elaboration and evaluation of those representations into useful outcomes. A constant stream of bottom-up stimuli, a chain of tweets for example, prevents this state of sustained attention and thus impairs processes that are conducive to creativity.

Recall the quote from above: “The fact that everyone has access to a wealth and diversity of ideas *and the means to actualize intent* means that we all can be more creative.” The ability to act on our ideas is a crucial element of creative cognition, but the ability to act on our ideas is undermined by recent digital technologies through the effects described above. It seems unlikely that the additional sensitivity to bottom-up stimuli will be enough to compensate for this loss in top-down control.

Yet, there are other ways that the use of recent digital technologies may foster creativity that we haven’t considered here, and that would benefit from future work. First, it may be that occasional use of these technologies foster creativity by providing inspiration during sticking points. Key to this will be the ability to recognize and make use of that inspiration, which will require that the impact of these technologies on cognitive control are short-lived. One might compare this to the use of altered states, such as those induced by certain drugs, to foster creativity; breakthroughs may occur, but they will only be useful if they are harnessed when the altered state subsides.

Second, individual differences may lead certain individuals to be more creative through even the habitual use of recent digital technologies. If we consider the balance of top-down and bottom-up control of attention as on a spectrum that varies across individuals, many individuals may be skewed relative to the best fit with their environment. For those individuals, altering the balance of top-down and bottom-up attention through the use of recent digital technologies may bring them into better alignment with their environment, and perhaps even allow for greater creativity. In other words, those with an excess in top-down control may benefit from a reduction in top-down control, even if this doesn’t necessarily help people in general.

Third, and finally, recent digital technologies may induce greater creativity through the content they provide. These technologies allow us greater access to books, academic articles, music, art, movies, and other content known to inspire creativity. Further, they allow us greater access to our social networks. Research on creativity in the business setting has found that individual creativity is important, but “the exposure to ideas from other team members and the use of creative problem-solving techniques may be at least as important.”[[24]](#footnote-24)

Thus, it may be that the benefits of recent digital technologies to creativity outweigh the deficits, at least for some individuals, but the harmful effects on attention remain. While we argued that exploration bias may have advantages in certain environments, we find that artificial salience is harmful when it leads to addictive disorders and when it is used to manipulate the user.

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