Perspectives on Creativity

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CHAPTER FOURTEEN

ANCIENT PRACTICES AND MODERN TECHNOLOGIES IN CREATIVE COGNITION RESEARCH

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This chapter will evaluate the potential of two novel techniques, transcranial direct current stimulation (tDCS) and meditation, for enhancing performance on creative cognition. These two techniques are intriguing candidates for comparison because they employ quite different methods yet can engage the same underlying cognitive mechanisms. Meditation, which includes a variety of techniques meant to train the mind to relax while maintaining awareness, is noninvasive, is learned through extended practice, and has relatively long-lasting effects on perceptual and cognitive abilities. TDCS involves the application of a weak electrical current that alters the activity of a region of the brain. It can either increase or decrease neural activity in a focal region, providing a variety of approaches for effecting complex cognitive processes such as creativity.

Both meditation and tDCS target a crucial aspect of creative cognition: disinhibition of unconscious associative thought. Theories of creativity have long recognized the role of the unconscious in producing novelty (e.g., Wallas, 1926; Martindale, 1999). Creative cognition is often described as occurring along a continuum of consciousness, where creative problem solving requires shifts in attentional focus, from a disinhibited state during idea generation to a tightly focused state during idea verification and elaboration (Wallas, 1926; Martindale, 1999). The creative process requires many iterations of moving between these extremes.

Research has established the existence of these different cognitive states and their importance in creative problem solving (e.g., Martindale &

Hines, 1975). Furthermore, the evidence suggests that people who solve creative problems more successfully have better access to the ability to shift between different cognitive states (S.A. Mednick, 1962). At the same time, this research generally does not suggest that more-creative people make these cognitive shifts consciously. It seems to be an intuitive, and probably unconscious, resource allocation that more-creative people simply do better (e.g., Ansburg & Hill, 2003; Carson, Peterson, & Higgins, 2003).

We contend that meditation and tDCS are powerful techniques that can directly effect access to cognitive states most conducive to creativity. The following section presents a neurocognitive theory of creativity that can be explored and enhanced through meditation and tDCS techniques. The final sections outline the existing research supporting the use of meditation or tDCS to understand and enhance creative cognition.

Neurocognitive theories of creative cognition

Current theories of cognition posit an inhibitory mechanism at the threshold of consciousness that frequently and actively suppresses large amounts of information (e.g., Cabeza & Nyberg, 2000; Eysenck, 1995; Fink, Grabner, Benedek, & Neubauer, 2006). This research is of interest to creativity studies for it implies that much information in the brain is unknown to consciousness. One theory holds that although the posterior regions of the brain (i.e., the temporal, parietal, and occipital lobes) continuously process tremendous amounts of information, the strict limits of human working memory force the frontal regions to inhibit most of that information before it reaches consciousness (Dietrich, 2003, 2004b; Heilman, Nadeau, & Beversdorf, 2003; Nörretranders, 1998).

If so much information is inhibited by the frontal cortex, creative cognition may be in part dependent upon what Dietrich (2003) calls "hypofrontality," a state of relatively reduced frontal activation and, thus, fewer inhibitory neural projections sent from frontal to posterior cortex. Dietrich (2004b) contends that creative cognition can originate from "deliberate" and "spontaneous" thinking instantiated in the frontal and posterior cortex, respectively. When functional fixation has set in, one can use the deliberate mode to methodically seek new strategies. In some instances, this by itself will produce a creative outcome. But, just as likely, a subsequent epoch of hypofrontality may be necessary to access relatively novel cognitive processes performed by the posterior areas of the brain. And, because frontal activity is reduced, the likelihood that posterior thought contents will surpass the consciousness threshold is increased.

Spontaneity will be experienced by the frontal lobes, which are unaware of posterior processing until its output is accessed suddenly by frontal working memory and consciousness (Dietrich, 2003).

Several lines of research suggest that hypofrontality, most likely following a stage of focused, conscious thought, contributes to creative cognition. Case studies have played a central role in the development of the notion that dreams and daydreams, both thought to be largely beyond conscious control, are critical in eminent mathematical and scientific reasoning (Ghiselin, 1952; Poincaré, 1952). In addition, a small body of empirical research on sleep has examined creativity. The REM stage of sleep is characterized by reduced frontal dorsolateral and increased posterior activity (Maquet, Laureys, & Peigneux, 2000), and subjects awakened in these states perform better on tests of cognitive flexibility (Walker, Liston, Hobson, & Stickgold, 2002). After sleep, research has shown, subjects increase recognition of hidden patterns (Wagner, Gals, Hilde, Verleger, & Born, 2004). By contrast, sleep loss impairs flexible thinking and the ability to update plans, but not critical reasoning (Harrison & Horne, 1999). Cumulatively, these sleep studies support a link between reduced frontal and increased posterior brain activity with performance on divergent tasks, a pattern that we believe corresponds to the effects of meditation upon the brain, and one that tDCS can induce.

Another intriguing line of research may reveal that a normally functioning brain inhibits certain creative impulses. Miller and others have found a group of people with no prior artistic inclinations who, typically following strokes, presented with degeneration of the prefrontal cortex and anterior section of the left temporal lobe, the latter housing critical language areas (Antérion, Honoré-Masson, Dirson, & Laurant, 2002; Lythgoe, Pollak, Kalmus, de Haan, & Chong, 2005; Mell, Howard, & Miller, 2003; Miller, Boone, Cummings, Read, & Mishkin, 2000; Miller et al., 1998; Miller & Hou, 2004). In significant numbers, these patients developed artistic impulses following frontotemporal dementia, sometimes simply whistling obsessively and sometimes producing quality visual art. Various researchers have found that artists who suffer from Alzheimer's and other neurodegenerative diseases sometimes experience stylistic changes but no decline in the expert-rated quality of their work (Annoni, Devuyst, Carota, Bruggimann, & Bogousslavsky, 2005; Bogousslavsky, 2005; Chatterjee, 2004; Espinel, 1996; Kleiner-Fisman & Lang, 2004; Lythgoe et al., 2005; Smith, Mindelzun, & Miller, 2003). Miller and colleagues interpreted this behavior as evidence for "disinhibition" of posterior and right-lateralized areas especially adept at creative cognition. Kapur (1996) called this phenomenon "paradoxical functional facilitation" to indicate that degeneration in one network might in fact improve or increase function in another. These experiments suggest that hypofrontality may indeed be an important aspect of creative cognition.

The following sections will provide examples of how meditation, an ancient practice, and tDCS, a modern technology, can both be used to induce hypofrontality, which we believe is a critical stage in the creative thought process.

Meditation

In meditation, people are challenged to gain finer control over their cognitive states. Meditation involves practice—not practice of specific tasks, but rather practice of controlling one's mind focus. This makes it an ideal candidate for enhancing access to creative problem solving, and in particular for problems that require efficient use of cognitive resources to achieve insight.

Meditation is practiced in many forms but generally can be categorized as either mindfulness-based or concentrative (Cahn & Polich, 2006). Mindfulness-based meditation encourages heightened awareness of a wide range of internal and external events and associated thoughts. Meditators are taught to be receptive to all cognitive events, including thoughts, emotions, sensations, and images that pass through their mind, without stopping to reflect on any one. This has been called maintaining a "wide-angled lens" (Valentine & Sweet, 1999) and is meant to gain greater understanding of the processes of consciousness. In contrast, concentrative meditation encourages a narrow "zoom lens" focus. Meditators are taught to identify one event, such as a repeated mantra or their breath, and to focus on that event to the exclusion of all others. Both forms of meditation involve heightened access to attentional processes, but it is mindfulness-based meditation that has the strongest links to improving creativity and the underlying skills that support creative cognition.

Here we explore some of the parallels between mindfulness-based meditation and creative cognition, noting of course that while the patterns are similar, no causality should be inferred.

Perceptual awareness

Mindfulness-based meditators compared with nonmeditators show heightened perceptual awareness as measured by sensitivity to light flashes (Brown, Forte, & Dysart, 1984), and more-creative people compared with less-creative people show faster response times to simple stimulus presentations (Vartanian, Martindale, & Kwiatkowski, 2007), as well as larger skin potentials (i.e., galvanic skin responses) to moderately intense tones (Martindale, Anderson, Moore, & West, 1996).

Cognitive disinhibition

Mindfulness-based meditators compared with a group instructed to nap daily (a common control group in meditation studies) showed significantly higher scores on an embedded figures task (Chan, 2004; So & Orme-Johnson, 2001), a task that requires defocused attention for successful performance. Creativity and embedded figures test performance are also related positively (see Miller, 2007; Morris & Bergum, 1978).

Neurocognitive markers

People showed increased theta and alpha wave activity while solving creative problems while meditating ("state" meditation effects), and after long-term meditation practice, but not while meditating ("trait" meditation effects). Theta and alpha wave activity are the slower brain wave activity that is associated with unfocused but conscious thought, such as in daydreaming, or lightly unconscious thought, such as with REM sleep. In addition, individuals showed increased right prefrontal activiation while engaged in both meditation and creative activities (Cahn & Polich, 2006).

Divergent thinking

There is also evidence to suggest a direct link between practicing mindfulness meditation and increased creative performance. The strongest support comes from a study using Transcendental Meditation techniques (So & Orme-Johnson, 2001). After six months of daily meditation on school days, high school students showed increased divergent thinking ability and improved embedded figure ability. These improvements were in comparison with the meditation group's pretest levels (within group) and a nonmeditation group's pre/post test difference scores (between groups). In a qualitative study, Dewey, Steinberg, and Coulson (1998) found that artists who experienced blocks in their creativity reported using meditation techniques to overcome those blockages.

Creativity and mindfulness

A mindful person and a creative person can be described and assessed similarly. The Toronto Mindfulness Scale (Lau et al., 2006) has two main components: *decentering* and *curiosity*. Decentering is described as the ability to self-regulate attention, perform attention switching, and inhibit elaborative processing. Curiosity is described as the quality of relating to one's experience within an orientation of inquisitiveness, experiential openness, and acceptance. By definition, decentering and curiosity are also part of most definitions of creative cognition. For example, Martindale (2007) describes creative cognition as tending to occur "in states of reverie in which cognition is disinhibited in the sense of not being hierarchically organized or guided by purpose or design" (p. 1778). These states of reverie are quite similar in definition to the mindfulness notions about decentering. Furthermore, Martindale finds that more-creative people show more extraverted personality traits, which he explains as support for the "disinhibited" personality of the creative person, similar to the curiosity component in the mindfulness scale.

Transcranial direct current stimulation

In the previous two sections, we discussed how theories of creativity stress the importance of disinhibition, and that meditation appears to improve perceptual awareness and unconscious, associative thought. We now present the case that a recently rediscovered technology (Wassermann & Grafman, 2005) will allow researchers to mimic the core brain states associated with creativity.

Transcranial direct current stimulation (tDCS) is a technology still in its infancy, yet neurocognitive researchers may find it of special value. Brain stimulation uniquely links the brain to behavior (Knoch et al., 2008), and for this reason it is a "tool of discovery" (Sackeim & George, 2008) that may create new approaches in neurocognitive research. Our core interests in creative cognition can be assessed by tDCS in unique and likely revealing ways. In this section, we first explain what tDCS is and how it works, and then we elaborate upon how this technology can help us design constrained experiments that illuminate the neurocognitive underpinnings of complex behaviors associated with creative output, such as meditation.

TDCS uses a weak electrical stimulation applied to the scalp to influence the activity of underlying brain regions. A tDCS device is small enough to be handheld and is powered by a single 9-volt battery delivering

a current of generally 0.5 to 2 milliamperes for up to 20 minutes (Wagner, Valero-Cabre, & Pascual-Leone, 2007). Two wires run from the device and are attached to separate electrodes placed on the scalp, and when the device is turned on, an electrical current passes through the scalp, skull, and brain between the two electrodes. One wire carries the positive charge and the other the negative. When the two are placed at some distance on the scalp, the current is completed as it passes through the head.

TDCS can increase or decrease neural firing in a particular region of the brain. Depending on the montage (arrangement) the researcher uses in attaching the wires to the electrodes, the current can run either to a particular region of the brain or away from it. By placing the anodal electrode over the researcher's primary region of interest, the likelihood of neural firing will increase (Nitsche & Paulus, 2000; 2001). If the two wires are switched and the cathodal electrode is over the region of interest, neural firing in the region will decrease. Thus, anodal stimulation increases, and cathodal stimulation decreases, the likelihood that an incoming stimulus (e.g., a picture seen or a sound heard) will cause neurons to reach their firing threshold. As a consequence, cognitive processes that depend on the affected region of the brain can be either enhanced or impaired.

The small body of existing tDCS research has shown the technology to be safe. One safety study found that subjects tolerated stimulation very well (Iyer et al., 2005), and another found very low incidences of minor adverse effects, such as headache and nausea, among normal subjects and clinical post-stroke or migraine patients (Poreisz, Boros, Antal, & Paulus, 2007). A third study found that most subjects rated as comfortable the first two minutes of stimulation (Dundas, Thickbroom, & Mastaglia, 2007), when the sensation tends to be strongest. TDCS is generally not used on those who have, or have a family history of, seizure disorders, such as epilepsy. As research grows, an effort must be made to further explore the safety considerations over the short- and long term.

In most studies, the effects of anodal and cathodal stimulation are compared to a sham condition in which the current is turned on for 10-30 seconds such that subjects experience the typical initial tingling on the scalp, but then the current is surreptitiously ramped down and turned off. Subjects are largely unable to determine whether or not they received real or sham stimulation (Gandiga, Hummel, & Cohen, 2006). One session of tDCS for 20 minutes can lead to effects on underlying electrical activity that can last as long as an hour (Nitsche & Paulus, 2001), but observable behavioral effects appear to last for only up to half an hour (Vines, Schnider, & Schlaug, 2006). The sham condition effectively becomes the baseline control condition in a within-subjects experimental design. Because the behavioral effects of stimulation last for up to half an hour, researchers have ample time in which to assess complex cognitive performance, comparing real to sham stimulation, or two different "brain conditions" in a single subject.

Only recently have tDCS experiments begun to grapple with complex cognitive tasks, yet nonetheless several studies shed light on how the technology might be used to do so. Here we review a select body of existing tDCS research that may bear on our core interests in creative cognition.

Working memory, or the ability to hold in mind several pieces of information, may impact creativity by affecting the number and breadth of items to associate in novel ways. Training working memory has been shown to increase fluid intelligence (Jaeggi, Buschkuehl, Jonides, & Perrig, 2008). Fregni et al. (2005) stimulated a region of the dorsolateral prefrontal cortex of the left hemisphere while administering a demanding 3-back memory task (i.e., remembering the stimulus three prior to the current one in a series of ongoing, rapidly presented stimuli). They found that anodal stimulation, which increases the likelihood of neuronal activity in the region, improved working memory, whereas cathodal stimulation had no effect.

Other tDCS researchers have examined decision making and executive function, the latter encompassing such abilities as planning, and maintaining or redirecting attention. In one study (Kincses, Antal, Nitsche, Bártfai, & Paulus, 2003), subjects were presented four shapes in various constellations that predicted one of two outcomes. Subjects were told no rules about the shapes and constellations but learned to connect pattern and outcome by trial and error. With anodal stimulation of left polar frontal areas, subjects improved on this task of probabilistic classification learning. A fascinating study by Knoch et al. (2008) shows how tDCS might be used in social neurocognitive studies. The researchers applied tDCS simultaneously to six participants who were playing the role of responder in an ultimatum game in which they decided to accept or reject offers made by others about how to split a pool of money. When participants received cathodal (blocking) stimulation of right dorsolateral prefrontal cortex, they were more likely to accept offers that gave them an unfairly small portion of the money.

Iyer et al. (2005) conducted the first study using a complex verbal task, moreover one with relevance to creativity. The researchers administered a task of verbal fluency (e.g., "List all the words you can think of that begin with the letter A") while groups of participants received active or sham

stimulation of the left dorsolateral prefrontal cortex. The researchers found that anodal but not cathodal tDCS improved verbal fluency marginally at 1 milliampere (mA) stimulation and significantly at 2 mA. Research by Cerruti and Schlaug (2008) built upon this study by assessing verbal fluency and another task associated with both creative thought (Ansburg & Hill, 2003; S. A. Mednick, 1962) and general intelligence (Andrews, 1975; S. A. Mednick & Andrews, 1967): the Remote Associates Test (RAT), developed originally by Mednick (M. T. Mednick, Mednick, & Jung, 1962) and refined by Bowden and Jung-Beeman (2003b). With 1 mA stimulation, no effect on verbal fluency was found, but a significant improvement in RAT performance was found when the left, but not right, dorsolateral prefrontal cortex was stimulated.

Direct stimulation may have effects on perception. Antal et al. (2004) applied stimulation to area V5 in the occipital cortex while subjects used a joystick to track a moving cursor on a computer screen. They found that visuo-motor coordination and learning was improved by cathodal stimulation of V5, an enhancement they attributed to perceptual and not motor functions. A study on pain perception found that anodal stimulation of the primary motor cortex increased the perceptual threshold at which participants felt a peripheral electrical stimulus of the index finger (Boggio, Zaghia, Lopes, & Fregni, 2008). More studies must be conducted before a clear understanding of the effects of brain stimulation on perception itself is gained. Nonetheless, these two studies suggest that perception of both external (e.g., a moving cursor) and internal (e.g., pain) events can be modulated by direct current stimulation.

The studies reviewed above generally show that increasing activity (with anodal stimulation) in a particular region of the brain can improve performance on certain tasks. While this is of clear interest to many researchers and clinical practitioners alike, cathodal stimulation may be of special interest to creative cognition researchers. Interregional inhibition, often interhemispheric inhibition through the corpus callosum connecting the two hemispheres, is a fundamental operating principle among the brain's many interconnected networks; strong activity in one region can inhibit activity elsewhere. The two polarities of tDCS affect neural firing in a main region of interest, but the modulated firing rate in this main region also has "downstream" effects on other regions. By blocking activity in one region, cathodal stimulation also reduces inhibitory neural projections from that region onto others. The neurons in these other regions, then, because their activity is being inhibited less than normal, are free to fire more strongly.

One fascinating study makes the importance of these downstream, disinhibitory effects clear. Vines, Nair, & Schlaug (2006) asked subjects to perform a complex finger-tapping exercise with left and right hands, and they applied both polarities of stimulation to the motor cortex of subjects' left hemisphere. Because the left hemisphere controls performance of the right hand, it was interesting, yet somewhat expected, that anodal, or positive, stimulation increased motor coordination of subjects' right hands. Considerably more striking was that cathodal (or depressing or blocking) stimulation, in fact, increased finger-tapping performance in the left hand. Depressed left motor cortex activity was postulated to disinhibit, and increase, right motor cortex activity, thereby improving left hand performance. To emphasize, depressing activity in one hemisphere led to performance that was better than normal in the hand controlled by the unstimulated hemisphere.

Given the centrality of disinhibition to creativity theories, cathodal stimulation offers particularly intriguing possibilities for research. Researchers might block activity in the frontal cortex and assess potential disinhibitory effects on creative cognition, as Dietrich's (2003) hypofrontality theory would predict. Or researchers might depress activity in highly verbal brain networks. Many studies by Wilson have shown that being forced to give verbal descriptions and introspections can impair nonverbal decision making (Wilson & Dunn, 1986; Wilson, Hull, & Johnson, 1981; Wilson & Schooler, 1991).

Directions for neurocognitive creativity research

The above review of existing neurocognitive theories of creativity, meditation research, and tDCS technology highlights three key elements that can be empirically assessed in neurocognitive creativity research. These elements are tightly interwoven and are presented distinctly for purposes of clarity. First, creative cognition is complex cognition involving different kinds of processes, and we have focused particularly on disinhibitory cognitive processes. Disinhibited thought is, in psychological terms, largely free from focused, goal-directed thought. In neurocognitive terms, disinhibition generally refers to a reduction of activity in the prefrontal cortex and a corresponding increase in posterior brain activity.

The second key element is that perception of both external and internal stimuli may be increased in creative cognition. Perception provides the contents for creative thought, even if the end result (a creative idea) is not immediately manifest. To understand this fully, especially perception of "internal stimuli," it is important to integrate the final component we consider important for the neurocognitive study of creativity.

Third, unconscious, associative thought is a core component of creative cognition. Conscious thought is considered a serial processor that can operate only sequentially on a small set of information. By contrast, unconscious thought is believed to operate in parallel (Nörretranders, 1998). Many regions of the brain, largely posterior, are continuously active but are relatively inhibited during highly focused, goal-directed conscious thought. As Miller (1956) famously observed, humans are only able to consciously process about seven pieces of information at a time. Nörretranders (1998) elaborates that a single "chunk" of information might be a well-rehearsed phone number one has memorized, but remembering a new phone number of seven or more digits is difficult. By contrast, the processing capacity of the unconscious is enormously larger—more than 10 million pieces of information (Nörretranders, 1998)—speaking to the importance of maintaining access to posterior thought contents. When prefrontal brain activity is reduced, the likelihood that the contents of posterior thought will ultimately reach consciousness is increased.

These three elements may not be an exhaustive list of the components of creative cognition, yet they are the three variables that we believe can be readily assessed in constrained neurocognitive creativity experiments.

TDCS can help reveal inhibition and disinhibition in an important manner that imaging technologies such as fMRI cannot. Both anodal (positive) and cathodal (blocking) stimulation can directly affect behavior independent of other changes (e.g., environmental conditions or task demands). TDCS is not necessarily a superior technology for all purposes, but it offers unique opportunities to creative cognition researchers. Reduced activation in a region of the brain creates what some have called a "virtual lesion" (Hilgetag, Théoret, & Pascual-Leone, 2001) or a "functional lesion" (Sackeim & George, 2008) in that area, which can disinhibit a second, interconnected region. Miller's frontotemporal dementia patients, discussed earlier, experienced spontaneous creative output, and with tDCS, researchers might empirically test in a constrained manner the implications of these natural experiments.

Mindfulness meditation and tDCS are quite different techniques that may be able to engage the brain in a similar fashion. Given the central place of disinhibition in theories of creativity, techniques such as these that can induce it will be very valuable to testing, and advancing, theories of creativity.