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Abstract

The Problem.

An uncertain economy with a highly mobile workforce compels employers to rely heavily on HRD research for empirically based selection criteria and proven predictors of job performance. One of those predictors is the ability to think analytically and critically. Evidence is mounting that heavy use of electronic media may impact the ability to think critically because of increased distractibility and inattention to work related tasks.

The Solution.

Collaborative research with medical and educational communities is needed to correlate impacts of heavy electronic media usage to critical thinking and, if confirmed, develop critical thinking measures and curricula that strengthen critical thinking skills in children and young adults entering the workforce.

The Stakeholders.

Confirming the effects of heavy electronic media on critical thinking will increase the body of research for medical professionals about brain functioning, inform education researchers about trends in student populations experiencing lower test scores, and provide HRD researchers information about developing engaged and productive employees.

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Keywords

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The global marketplace of the 21st century is being populated by the millennial or Net generation, born between 1982 and 2000 (Lancaster & Stillman, 2010). They are the generation who, since birth, have been immersed in television, video games, computers, and cellular technology. From a human resource development (HRD) perspective, they bring social networking skills that are beneficial to staying ahead of the competition, especially in a tumultuous and uncertain economy. An issue of *Advances in Developing Human Resources*, published in 2010, was specifically devoted to the role of virtual human resource development in the training and development of this cyber connected, millennial generation. Nearly all of the authors suggested that performance is enhanced by delivering training in a context that suits the millennial. Setting all this uber-connected excitement aside, HRD researchers need to look deeper to see if there might be some negative effects of heavy electronic media usage manifesting in poorly performing student populations from the millennial generation and our future workforce.

Two recent examples illustrate concern by both industry and the federal government over the numbers and quality of students entering math and science related disciplines. The first example is a recent series of television advertisements for a global oil company that highlights some sobering statistics about how the test scores of children in the United Sates have fallen in the last half century (http://www.nationalmathandscience.org). In a second example, Floersheim and Johnston (2010) noted that of all the countries in the Organization for Economic Co-operation and Development (OECD), the "United States is in the bottom quarter of OECD countries for math and in the bottom third of OECD countries for science" (p. 3). These statistics are sobering considering the billions of dollars promised by President Obama under the "educate to Innovate" campaign in 2009 (Floersheim & Johnston, 2010).

Wagner (2009) argued that "the Net generation isn't reading newspapers or books at the rates that their parents and grandparents do, but that does not mean they are less informed" (p. 53). There is a growing concern however, that increased use of electronic media has resulted in increased distractibility, changed critical thinking skills and impacted the way we approach complex problems (Greengard, 2009). Critical thinking is becoming a necessity in our modern chaotic markets (Samli, 2010). Muller and Turner (2010) found that critical thinking ranked as the highest competency in successful project managers in every application type, level of complexity, importance and contract type. Commenting on the role of innovation in the highly competitive market of health care, Cohn and Newbold (2009) stated that "innovation transcends new technology" (p. 367) and facilitating innovation requires "stakeholders to replace traditional critical thinking ('yes, but . . .') with breakthrough thinking ('yes, and . . .')" (p. 364). In an uncertain economy, in the midst of global competition, critical thinking and innovation might mean the difference between success and failure of individuals, businesses and nation states.

If the millennial generation is so well informed, why are test scores dropping and why are we spending millions of dollars to coax them into math and science programs? Is simply providing employees access to vast amounts of instantly available information a path to maximizing human capital? A recent book by Nicholas Carr, *The Shallows: What the Internet Is Doing to Our Brains*, highlights these and other concerns about the deleterious effects of heavy electronic media use on our thinking. Following Carr's research, literature on brain research as it relates to plasticity, distractibility, and critical thinking was reviewed to provide an overview of what is known and unknown about the possible linkage of electronic media use to distractibility or divided attention and critical thinking. In addition to several recent books on electronic media and thinking, peer reviewed journals were searched using keywords including distractibility, attention, critical thinking, and neuroplasticity. Literature that connected two or more of the terms was reviewed to provide a basic understanding of the brain and how it works, the ability of the brain to change in response to external stimulation like electronic media, and different types of thinking possibly related to skills required in the workforce. Although we all use some amount of electronic media, the main focus of the review was the millennial generation and younger because they have been more heavily exposed to electronic media since birth and they comprise much of our present and future workforce.

The Brain's Ability to Change

The ability to reason and think critically have always been essential to the survival and wellbeing of humans. Medical researchers for centuries speculated which parts of the brain might be responsible for mental abilities and emotions (Carr, 2010). Not until 1924, when Hans Berger produced the first electroencephalograms, did researchers link the electricity in the brain to brain functioning and its changes in response to stimuli (Hass, 2003). Researchers can now see the inner-workings of the brain by using technologies like functional magnetic resonance imaging (fMRI; Shaywitz, Lyon, & Shaywitz, 2006). A closer review of the brain will be helpful to understand the brain's ability to change, including becoming more distracted, and how those changes might be observed and measured. The following sections will provide a rudimentary understanding of brain functioning, the network of connections, or mapping, involved in brain functioning, neuroplasticity or the brain's ability to change, and how brain functioning can be interrupted, rerouted, and reconnected.

Basic Brain Functions

The brain is made up of an outer layer called the cerebral cortex. This tissue is divided into four lobes: the frontal lobe: responsible for thinking, decision making, and motor skills; the parietal lobe: responsible for most body sensation; the temporal lobe: responsible for hearing, vision, smell, and some memory; and the occipital lobe: responsible almost exclusively for vision. In recent years, scientists have been able to confirm that lateral prefrontal and posterior parietal regions play key roles in working memory and attention (Hampshire & Owen, 2006). The cerebral cortex is also divided into right and left hemispheres each having the four lobes described above. In addition to the cerebral cortex there is also a cerebellum and brain stem that support the brain. Two other important parts of the brain are the hippocampus; responsible for memory and the amygdala; responsible for emotion. There are three crucial areas of the brain,

> . . . a section of the frontal lobe called the ventromedial prefrontal cortex, which is central to both emotional processing and decision making; the somatosensory cortex in the right hemisphere, which interprets information coming from the body; and the amygdala, the almond-shaped area within the temporal lobes that plays a crucial role in emotional response. (Johnson, 2009, p. 37)

Brain Mapping

In addition to mapping the connections of the brain at work, mapping the brain at rest is being pursued by medical researchers for several reasons.

> One of the most intriguing puzzles in cognitive neuroscience is the existence of a set of brain regions—the default-mode network—that exhibit greater signal during baseline or rest periods of functional neuroimaging studies than during performance of effortful cognitive tasks. (Gilbert, Dumontheil, Simons, Frith, & Burgess, 2007, p. 43)

This description of the brain's functioning at rest is called functional connectivity and the architecture of detailed map is called functional connectome (Biswal et al., 2010). There are two hypotheses about what activity goes on in the default-mode network while the brain is resting. The first is the stimulus-independent thought (SIT) hypothesis. These are cognitive processes unrelated to the current task and not as a result of sensory input; mind wandering, dreaming, or perhaps storing and retrieving memories. The second is the stimulus-oriented thought (SOT) hypothesis. These cognitive processes are waiting for signals from the senses that are relevant to a task at hand (Gilbert et al., 2007). The importance of this debate is to determine if we can isolate and measure distractibility. If researchers are able to measure distractibility in a resting state they might be able to correlate the effects of electronic media or other causes. Further research will be needed to demonstrate this ability to positively isolate distractibility in functional connectomes.

Neuroplasticity

The brain's ability to change is an underlying phenomenon that must be present for researchers to pursue a possible connection between external stimuli and resulting changes in brain functioning.

> Neuroplasticity is the brain's ability to reorganize itself by forming new neural connections throughout life. Neuroplasticity allows the nerve cells in the brain to compensate for injury and disease, and to adjust their activities in response to new situations or to changes in their environment. (Taupin, 2005, p. 12)

In more simple terms, neuroplasticity is the ability of the brain to change its network connections in response to either internal or external stimuli. This is important to the debate about the effects of electronic media on the brain because when new stimuli like electronic media are introduced, processing that media takes the place of other brain functions. An example of how this happens is the neural connection to muscle memory. When humans learn a new skill the brain first reacts with attention in the frontal lobes. The visual cortex or occipital lobe springs in to action next, visualizing the motion at the same time the parietal cortex becomes engaged to remember similar experiences. Finally, the somatosensory or motor cortex sends the signals to the muscles to move. In recreational programs that teach swimming to children and adults with disabilities, muscle memory compensates for reduced visual, hearing or processing capacity, particularly in the case of people with autism. The first steps in the process; attention, visualization, and association can be disrupted or missing leaving only rote memorization of a physical action to teach the skill. Amazingly though, the simple act of moving the arms or legs in a certain way over and over again creates a muscle memory that is sufficient enough to learn a skill like a flutter kick or a frog kick.

Rerouting Network Connections

The "somatosensory cortex is a map that reflects the distribution and density of receptors on the body surface" (Killackey, 1989, p. 3). Dr. Michael Merzenich's studies of somatosensory cortical maps in adult monkeys have had an impact on how scientists view dynamic mapping of sensory mechanisms in humans (Merzenich et al., 1984). In one test, Merzenich exposed a monkey's brain and mapped the sensations caused by tapping on its fingers and hand. The second stage of the experiment was to sever the sensory nerve to the hands and observe the reaction. He expected the nerve which had been severed to regenerate but what he did not expect was that the brain would restore the map in a healing process. In a later review of his work, Merzenich et al (1984) found that cortical maps are dynamically maintained. Herbert Killackey in the Departments of Psychobiology and of Anatomy and Neurobiology at the University of California, Irvine reviewed the studies done on mice and monkeys during the period of 1959 to 1988 and concluded that cortical somatotopic maps may not be particularly dynamic but cortical processing might be dynamic in that some receptors might be revealed or unmasked in response to injury or other interventions that disrupt past neurological responses (Killackey, 1989). Whether cortical maps are static or dynamic, researchers agree that the brain is capable of reorganizing or rerouting stimulus responses for whatever reason, to complete their sensory circuit.

Reconnecting and Relearning Brain Functions

There is a growing body of research that confirms a long held suspicion about the brain's ability to adapt after injury. Neurogenesis, the formation or regeneration of nerve cells, has been observed in patients who have suffered cerebral strokes and traumatic brain injury as the primary contributor to recovery (Taupin, 2005). Another study done in Switzerland found that the "cerebral anatomy of deaf individuals has undergone structural changes as a function of monomodal visual sign language perception during childhood and adolescence" (Meyer et al., 2007, p. 335). This difference in the physical structure and shape of the brain of people that have been deaf since birth indicates that not only can the brain reroute the network it uses for the senses and other functions, it can also develop specifically to accommodate the use of certain substructures. This demonstration of plasticity of the functional and structural organization of language regions in the brain added much to the body of knowledge (Meyer et al., 2007).

Neuroplasticity has also been observed in the treatment of developmental differences. "Developmental dyslexia is characterized by an unexpected difficulty in reading in children and adults who otherwise possess the intelligence and motivation considered necessary for accurate and fluent reading" (Shaywitz, Lyon & Shaywitz, 2006, p. 614). Dyslexia can be observed using functional magnetic resonance imaging (fMRI). Dr's Bennett and Sally Shaywitz have used fMRI to isolate disruption of the left hemisphere posterior systems, used by nondyslexics for reading, and a compensatory engagement of the anterior systems around the inferior frontal gyrus and right occipital-temporal system in dyslexics. Shaywitz found that the poorer the reader, the greater the activation in the right occipital-temporal region (Shaywitz et al., 2006). In a more recent study, Dr. Shaywitz, along with other researchers, was able to demonstrate a coupling between cognition and reading in typical readers and a developmental uncoupling between cognition and reading in dyslexic readers (Ferrer, Shaywitz, Holahan, Marchione, & Shaywitz, 2010). Using data from the Connecticut Longitudinal Study, a study that tracked school children from kindergarten through the twelfth grade, they were able to correlate reading ability and IQ scores. Their findings indicate that dynamic interrelations between reading and IQ over time account for differences in reading development and dyslexic's intellectual development may depend more on other environmental inputs than simply reading (Ferrar et al., 2010). An important finding, and good news for dyslexics and their parents, was that early and effective intervention uses the brain's plasticity to change the neural systems and actually engage the left hemisphere posterior systems, used for reading.

The Effects of Heavy Electronic Media Use

The human brain thirsts for stimulation. Electronic media quenches that thirst by offering a plethora of data and images at the click of a mouse or a touch of the screen.

Consumers demand faster and faster computers, more applications for their handheld devices and sometimes have so many windows open on their computers that it's hard to keep up with all the things they are doing at the same time. Search engines profit from directing readers to advertisements using hyperlinks and other distractions on the borders of the page. The reader's attention is further divided by pop-ups, e-mail notifications, and beeps and buzzes on other devices. The millennial generation actually prefers skimming and scanning to traditional modes of reading. They have been conditioned to skim over greater quantities of often superfluous information but seldom take time to read deeply and fully and digest the meaning of what is being read and then turn that meaning into deliberative, critical thinking.

Memory

A concern surrounding the heavy usage of electronic media is its effect on memory. There are two types of memory; working memory and long-term memory. Working memory takes place in the dorsolateral prefrontal cortex and is comprised of encoding, maintenance and retrieval (Taylor et al., 2004). The amount of information a person can hold in their working memory, called cognitive load, is limited. Agostino, Johnson, and Pascual-Leone (2010) investigated various aspects of children's mental-attentional capacity and how it contributes to multiplication word problem solving. They found that although there were no group differences on short term memory tasks, there was a noticeable difference in the use of working memory. Agostino et al. (2010) concluded that, "the person must reduce accessibility of less relevant information that could overload working memory and interfere during processing" (p. 228). The effect on long-term memory is just as significant. Working memory has to sort through data and apply reason or emotion to it before it can store information in long-term memory. When the working memory is repeatedly inundated with more and more stimuli, the brain is said to be in cognitive overload.

Cognitive Overload

Two sources of cognitive overload are extraneous problem solving and divided attention (Carr, 2010). When the brain is in cognitive overload it loses the ability to move the information from working memory to long term memory thereby creating knowledge. Anatomically speaking, the prefrontal cortex is overloaded by hyper-attention to minute task after task, requiring constant low level decision making, and leaving no capacity for digesting what has been read. Small, Moody, Siddarth, and Bookheimer (2009) found that heavy Internet users showed a greater amount of activity in the dorsolateral prefrontal cortex, the area used for critical thinking and decision making. Although valuable in keeping the mind active, this constant bombardment of the prefrontal cortex for split second decisions about where to click next can supplant the brain's capacity for more deliberate processes like thinking critically.

Divided Attention

Ophir, Nass, and Wagner (2009) found that "heavy media multitaskers are distracted by the multiple streams of media they are consuming, or, alternatively, that those who infrequently multitask are more effective at volitionally allocating their attention in the face of distractions" (p. 15585). The brain actually gets used to performing superficial tasks by supplanting the working memory with a constant flow of information, jumping from task to task leaving little or no time for organization of thought or gaining meaning from anything that has been read. This "mental ping-pong" can result in anxiety and forgetfulness.

Decision Making

Another concern about this never ending barrage of digital media on the brain is the effect that it has on decision making. Antonio Damasio, the Director of University of Southern California's Brain and Creativity Institute, tells the story of one of his patients who suffered brain damage to the prefrontal cortex (Johnson, 2009). A lack of decision-making ability was observed when his patient was presented with a simple choice of two appointment dates. While the patient could analyze all the factors influencing the decision, making the decision was beyond his ability. The same patient relayed his lack of reaction to seeing a car in front of him hit an icy patch, spin out of control, and without any fear or second thought, driving right through the same icy patch. Even though he made it over the patch safely, his reaction, or lack of reaction, showed clear emotional detachment (Johnson, 2009).

Intuitive Thinking Versus Critical Thinking

Having established that critical thinking is a highly desirable competency in employees, (Muller & Turner, 2010; Samli, 2010) and innovation depends on critical thinking skills, (Cohn & Newbold, 2009), a recent book written about how we think about thinking was germane. In his book, *Thinking, Fast and Slow*, Daniel Kahneman (2011) distinguishes two types of thinking; System 1 or "fast thinking", which is intuitive, perceptive and is the "secret author of many of the choices and judgments" we make, and System 2, or "slow thinking" which is a "more deliberate and effortful form of thinking" used for analysis of data (p. 13). "System 2 is the only one that can follow rules, compare objects on several attributes, and make deliberate choices between options" (p. 36). Many professions, particularly in the science and engineering, require this type of deliberate, critical thinking using problem-solving approaches (Floersheim & Johnston, 2010).

> Critical thinking is that mode of thinking—about any subject, content, or problem—in which the thinker improves the quality of his or her thinking by skillfully analyzing, assessing, and reconstructing it. Critical thinking is

> self-directed, self-disciplined, self-monitored, and self-corrective thinking. It presupposes assent to rigorous standards of excellence and mindful command of their use. It entails effective communication and problem-solving abilities, as well as a commitment to overcome our native egocentrism and sociocentrism. (Foundation for Critical Thinking, 1987, A Definition, as cited in Hale, 2008)

Kahneman notes that "many judgments, especially in the professional domain, are influenced by a combination of analysis and intuition" (pp. 185-186). Practically speaking, having the ability to use both System 1 and System 2 thinking is desirable for everyone regardless of profession. Psychologists and neuroscientists have established that "executive control" or the "adoption and terminations of task sets" and switching from System 1 to System 2 thinking is also resident in the prefrontal cortex (p. 37). Additionally, studies done by Kahneman and others reveal that mental effort, like physical effort, follows the "law of least effort" causing people to gravitate to the least demanding source of thinking resulting in mental laziness (Kahneman, 2011, p. 35). This tendency of the brain toward a path of least resistance and the impact of excessive use of electronic media on executive control in the prefrontal cortex, gives credence to concern over the possible linkage of electronic media induced distractibility and critical thinking abilities.

Implications for HRD Theory, Research, and Practice

The goal of this article was to provide a compelling case for HRD researchers to consider that the millennial generation, already in the workforce, and the generation behind them who are even more immersed in electronic media, may be experiencing a reduction of their ability to think critically and analytically because of their heavy use of electronic media. As Glassman (2001) observed, "Adolescence is the first point at which humans are able to use thinking to make true individual judgments concerning their own activities" (p. 10). If, at this critical time of mental development, young adults are undergoing a change in their brain functioning that is symptomatically manifest in lower test scores and increased distractibility or divided attention, HRD researchers should join with medical and educational researchers to investigate this phenomena.

Falling Test Scores

A collaborative research agenda for HRD researchers and educators should include an investigation of the possible link between heavy use of electronic media and falling test scores in reading and other skills related to critical thinking. The Nielsen Company (2009) reported that "Time spent online among children aged 2-11 increased 63 percent in the last five years, from nearly 7 hours in May 2004 to more than 11 hours online in May 2009" compared with a 36% increase in time spent online for the rest of the population. Test scores indicate that the effect of electronic media use on children may be significant. During the period of 1999 to 2008, Internet and other digital device usage increased by more than 60% while critical reading scores dropped 3.3% and writing skills dropped 6.9% (Carr, 2010). Floersheim and Johnston (2010) found that test scores in science for 4th graders from 1995 to 2007 also dropped by 3%. The Condition of Education 2008 report from the National Center of Education Statistics also notes that average reading scores for 12 graders were 6 points lower in 2005 than in 1992. These trends in educational performance are concerning because verbal comprehension, reasoning and word fluency have been proven to be important predictors of job performance (Lang, Kersting, Hülsheger, & Lang, 2010).

Confluence of Increased Electronic Media Use and Increased ADD/ADHD Diagnoses

A second area of particular interest is the correlation of increased use of electronic media with the increasing diagnoses of Attention Deficit Disorder (ADD) and Attention Deficit Hyperactivity Disorder (ADHD) in the millennial and younger generations. In 1980, when the diagnosis criteria for ADD/ADHD first appeared in the *Diagnostic and Statistical Manual*, a diagnostic guide published by the American Psychiatric Association, some 500,000 children were diagnosed with the disorders; that number ballooned to more than six million in 2006 (Baughman, 2006). During the same period, television usage increased, video games, prevalent only in arcades years before, became introduced into households, and the personal computer revolution exploded with ever increasing numbers of average Americans having access to the Internet. This increased use of electronic media starting in the early 1980's positively correlates with the increased diagnosing of ADD/ADHD and tracks with the same population, the millennial generation. Since the diagnosis is based purely on behavioral factors and focuses on inattention and distractibility, it follows that a cause and effect relationship could be drawn. The prefrontal cortex is the last area of the brain to develop and is still developing during the teenage years (Siegel, 2011). This immaturity of the frontal lobes accounts for much of the impulsivity and lack of judgment seen in children through their primary and secondary school years. These biological and developmental deficiencies are perfectly normal but play a major role in the diagnosis of ADD/ADHD. The neurological evidence of electronic media induced distraction and studies on neuroplasticity support a linkage to over stimulation of the prefrontal cortex, used for working memory, resulting in decreased ability to hold attention (Carr, 2010; Seigel, 2011). As our knowledge base becomes even broader, there is a growing concern that ADD and ADHD may not be disorders but simply the result of a distracted, over stimulated, underdeveloped brain. More research is needed to confirm this thesis and should also include the effects of long term use of ADD/ADHD medication on our current and future workforce.

Teaching Methods

A final focus area for HRD and educational research is the efficacy of problem based learning methods and their relationship to critical thinking. Floersheim and Johnston (2010) found that "reduction and reorganization of topics introduced in secondary schooling is imperative for transitional learning from concrete to abstract concepts" that support critical thinking (p. 10). Comparing data from nearly 60 countries around the world, they found that class size, time spent on homework, teacher credentials, access to technology, and even funding spent per student were not nearly important as a curriculum that included the optimal "number and sequencing of topics studies" over the elementary and secondary years of schooling (p. 1). They also note that American textbooks contribute to distraction by excess use of diagrams, pictures, "fun facts" that detract from central themes and abstract concepts (p. 7). Some educational researchers have argued for greater use of teaching methods like the Socratic method to enhance students' learning by engaging in problem based, analytic thinking that results in higher test scores and graduation rates. Edelson (1996) describes Socratic case-based teaching a method that "engages the learner in a dialogue by posing open-ended, thought-provoking questions" (p. 357). Named for the philosopher Socrates, the Socratic method of teaching requires the student to prepare for class by reading background material and then engaging the teacher in debate over the issues covered by the material. Zabit (2010) asserts that mere knowledge is "not sufficient for learning" but using problem based learning like Socratic teaching enhances critical thinking (p. 8). More research is needed to determine the effectiveness of problem based learning on developing critical thinking skills.

It is important for HRD researchers to continue to pursue empirical studies and collaborate with the medical and education communities to determine if the increased use of electronic media has had a negative effect on critical thinking and if it has, determine what steps can be taken to increase critical thinking skills. This review of the literature has established that the prefrontal cortex, inundated by electronic media "is crucial for how we pay attention; it enables us to put things in the 'front of our mind' and hold them in awareness" (Siegel, 2011, p. 8). If this media induced distraction is affecting the way the millennial generation and younger generations channel their cognitive resources it is at least plausible that it could be partially responsible for lower test scores and increased diagnoses of attention related disorders.

Is there a cure for electronic media induced distractibility? As studies on dyslexics have proven, areas of the brain originally wired to perform certain functions such as reading, can be encouraged by deliberately and effectively exercising those functions. In the case of the prefrontal cortex, hijacked by the multitasking of electronic media, the answer might be heavy doses of old fashioned reading. Deep reading while filtering out distractions might result in restoration of the abilities originally designed for our prefrontal cortex; deliberate, critical thinking. Solving complex problems, seeking innovative solutions to challenges, and maintaining a competitive edge in the market all require deliberate and critical thinking.

It is in our best interest as HRD researchers to pursue a research agenda that collaborates with educational and medical researchers to further investigate the potential effects of electronic media on our current and future workforce. If a linkage to critical thinking is established, compensatory measures should be put in place by educators to develop more effective curricula and teaching methods that emphasize critical thinking skills in school-aged children. HRD professionals should also develop and encourage training and development programs that bolster critical thinking skills in the workforce.

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