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Research Notes

Applying neuroplasticity to educating agile-thinking managers

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ABSTRACT

Findings in neuroplasticity confirm that the brain continues to change over time, and that different types of experience result in different types of change (plasticity). Further, the type of plasticity change enables (or disables) or favors (or discourages) different thinking capabilities. Applying these findings, the authors offer an argument that the type of change enabled by teaching-to-repeat (T2R), a passive learning approach prevalent in business education, prepares students' brains to perform in a manner quite different from that valued by business practitioners. Of perhaps greater importance, educational methods of this sort actively discourage the type of brain development consistent with desired capabilities.

The authors propose pedagogy – teaching-to-vary (T2V), consistent with development of a different type of plasticity. They argue that by implementing techniques designed to foster variation, working against the brain's tendency toward a preference for the familiar, business educators can both mitigate T2R effects, and better prepare students' brains to manage in uncertain, often turbulent environments. Caveats and suggestions for future research are offered in closing.

1. Introduction

Both industry and academia have long called for substantive change in business education (e.g., Berggren & Söderlund, 2014; Cheit, 1985; Louis, 1990; Porter & McKibbin, 1988). At the heart of the issue is the view that business education does not sufficiently take into account needs of prevailing business practice, and that this has resulted in a "gap" between preparations provided and skills or capabilities required (e.g., Arum & Roksa, 2011; Lakhal & Sevigny, 2014; NACE's Job Outlook, 2016 Survey; Shah, Grenbennikov, & Nair, 2015; The Bloomberg 2015 Jobs Skills Report; The Chronicle of Higher Education 2013 Report on the "Employment Mismatch"). Practitioners' concerns largely involve the perception that graduates arrive on the job content-rich, yet ill-prepared to cope managerially with the dynamism of today's marketplace (e.g., Chia & Holt, 2008).

Many, like Tompkins (2001), describe the work environment as one in which the "right" answers are not clear, advising that students need the skill to think "anew" or in different ways that may involve defining problems differently. Yet too often

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practitioners find business graduates unprepared to function productively when situations are ambiguous or changing. Smith (2003) reported evidence that graduates are unable to think effectively or handle the demands of the job upon being hired. Humphries and Dyer (2005, p. 170) observed a "lack of questioning" (LOQ) phenomenon in the workplace, with graduates possessing a passive posture or demeanor, too willing to favor the status quo. They argue that this acceptance of situations or circumstances as "given" creates an illusion that works against good managerial decision-making. Athanassiou, McNett, and Harvey (2003, p. 534) observe that students "… lack an ability or willingness to frame interesting questions." Similarly corporate recruiters characterize MBA graduates as being "… unable to step outside of their comfort zones to explore new ways of thinking and doing" … unable "… to face today's problems and to acquire new knowledge" (Wankel & DeFillippi, 2006, p. 387).

Some, like Mintzberg and Gosling (2002) suggest that in its approach, traditional business education separates itself from business reality in that it is predicated on types of discipline-related borders (or boxes – theories/concepts devoid of context) that don't align with realities that managers must face. Ghoshal (2005) observes that presentations of management theories are decontextualizing, not revealing their ideological underpinning thereby freeing students in business settings from any sense of moral responsibility for conforming behaviors. Like others, Wright, Paroutis, and Blettner (2013, p. 92) address aspects of content, questioning the managerial usefulness of the "strategic tools we teach in business schools."

But how do pedagogies relate to outcomes? This question neither new, nor unique to business education. Numerous learning methodologies, either in support of or based on a variety of theoretical foundations, have been advanced in the education literature generally. These range from behavioral to constructionist; from collaborative to game-based (See, for example, Henry, 1997; Mills, 1998; Neisser, 1967; Serva & Fuller, 2004; Skinner, 1954).

Despite this plethora of options available to business educators, researchers still argue that learning analytic techniques alone do not necessarily translate into better decision-making (e.g., Mintzberg & Gosling, 2002). More recently Boyatzis (2014) argues that, from a neurological perspective, an excessive educational emphasis on analysis and analytical tools taken in business programs can lead to students becoming less social and less open to new ideas. Simply listening and talking about leadership doesn't necessarily make for good leaders, and managers must work with (or lead) people in accomplishing various tasks. Even knowing what to do is not the same as knowing when or how to do it, or, in a managerial context, how to get it done. Today this is increasingly likely to involve being open to new ideas, and having the inter-personal skills needed to relate to and motivate others with widely varying backgrounds in increasingly collaborative/cooperative relationships.

Business practitioners have specifically and repeatedly made clear that, from their perspective, better educational preparation means better production of graduates with the skills and capabilities needed to handle change, especially rapid change in complex contexts. To these ends, most educational researchers acknowledge that "passive" learning is inferior to "active" learning, and that "active" learning appears to enable more consistently positive outcomes (e.g., Matthews, 2014; Weimer, 2012). Less obvious, however, is the type of "active"-ness needed when the goal is to produce both a disposition towards change and a propensity for effective participation in change. Research results now indicate that a neurological perspective can be used to provide new insights into the ways different forms of learning condition the brain to operate in one manner or another. Effects of this sort have neither been considered, nor can their impacts be understood, in the context of more traditional learning perspectives. We argue that what transpires at the neurological level produces results evidenced at the psychological and behavioral levels (e.g., Hannah, Balthazard, Waldman, & Jennings, 2013).

Further, discussions concerning appropriate use of active and passive educational methods indicate that few suspect that "passive" learning might produce long-term negative effects. Recently published findings in brain research, however, indicate that the potential for such effects neurologically is very real. Through examination of brain plasticity, neuroscience is now able to provide insights into the different types of change that favor fixed or agile thinking. These findings permit development of an improved understanding of the potential long-term effects of "passive learning." Perhaps more productively, they allow us to identify those critical element(s) in "active learning" that can be used to develop agile-thinking business students, and graduates better attuned to the management of change.

The Task at Hand: We begin by further defining the agility construct offered by others to underscore the significance of agile thinking in a managerial context. Next we ask, "How does the brain change?" and, "How might advances in our understanding of neuroplasticity (the brain's ability to change) be used to better prepare business students to manage in the context of dynamic business environments?"

A brief explanation of the key points of neuro-plasticity is offered to provide perspective on how these relate to our interest in business education, and a comparison of representative passive and active teaching methods is offered. The characteristically passive method (often found in business education), is referred to as teaching-to-repeat (T2R). This is compared to a representative "active" learning approach that we call teaching-to-vary (T2V). From a neurological perspective, these two are contrasted to illustrate the quite different plasticity effects favored by each, and the relationship between these effects and the development of agile thinking capabilities. Research on the neurological concept of "plasticity" now makes it possible to compare forms of learning like these through examination of observable changes in brain physiology (e.g., by comparing MRI revealing differences in grey matter densities). This in turn allows consideration of how different forms of plasticity lead to different psychological and thinking outcomes, e.g., rigidity versus agility; creative, critical versus reflective thinking; affect versus cognitive. Our argument seeks to support the importance of this type of research for improving the educational preparation of business managers in the modern era.

In our final section, we offer teaching and future research suggestions based on the differences in neurological and agility-related outcomes apparent from the comparison of the two representative methods.

2. Agile thinking and business management

To deal with complexity, dynamism and ambiguity, Lazzara et al. (2010) found that "people must possess mental agility and the ability to adjust quickly yet accurately. Therefore, there is a need to train adaptive expertise to perform successfully." Further, Neuringer (2004, p. 672) points to the desirability of being able to respond to situations in a novel way: "Behaving in an unusual, variable, or unpredictable manner is sometimes functional. An individual may sample new paths to reach a goal, invoke varied strategies when competing with an opponent …"

The variable, adaptive thinking necessary for such behavior has come to be more commonly referred to as mental or thinking agility. However, can variability in thinking be taught? Neuringer asks: "Where does such variability come from? Why can some individuals 'be loose,' avoid ruts, and engage in novel actions, whereas others seem set in their ways? How do we increase or decrease variability when it is important to do one or the other – to behave in a non-traditional or creative way when that is needed, and to repeat practiced, predictable response when situations so demand?" (Neuringer, 2004, p. 672).

If agility could be conceptualized as a set of thinking skills that could be learned, teaching these skills might offer business education a way to produce students more adept at modern management practice. In the book entitled "The Agile Mind," Koutstaal (2012, p. 12) offers an extensive review of the debate on the agility phenomenon from a psychological perspective. It is concluded that agility encompasses both skill in process and skill in content, and that both are necessary for navigating diverse and variable situations. From this perspective, mental agility is the ability to move back and forth along a continuum from automatic (habitual) processes to controlled (more involving, engaged thinking) processes and at the same time, be able to move back and forth along a continuum from concrete to abstract content. Yet Koutstaal, like the work of those criticized, neglects the importance of the neurological aspects of agility.

Taking both psychology and neuroplasticity into account, we offer the following as a more comprehensive attempt to describe mental agility or thinking agility (here simply referred to as agility).

> **Agility** is the inclination and ability (skill) to more fully utilize existing brain connections/neuro-networks across hemispheres and moreover to continuously create new ones. These new brain connections/neuro-networks allow differing forms of content to be formed or utilized via differing means of processing (synchrony). Agility involves the movement/synchronization among existing brain connections/networks along with the inclination and ability (skill) to continuously create new ones – that is to vary.

Agility so defined involves both seeking new forms of representation, and developing an inclination to continue this seeking process, resisting or avoiding blind acceptance of already formed representations. This process of continually seeking new forms of thinking (to vary) neurologically leads to more expansive, complex and evolving neuro-networks while simultaneously increasing the brain's density due to the increase in connections/networks and general intelligence (g-intelligence).

3. Neuroplasticity—how the brain changes

Neuroplasticity (plasticity) simply put refers to the brain's ability to change, as a result of different experiences, through creating and changing synaptic connections/networks and the synchrony to fire them (LeDoux, 2002). Synapses are how brain cells (neurons) communicate among themselves. The typical brain has approximately 100 billion neurons and "Each neuron may be connected to up to 10,000 other neurons, passing signals to each other via as many as 1000 trillion synaptic connections" (Mastin, 2010). Accordingly, "neural activity can modify the behavior of neural circuits by one of three mechanisms: (a) by modifying the strength or efficacy of synaptic transmission at preexisting synapses, (b) by eliciting the growth of new synaptic connections or pruning away of existing ones, or (c) by modulating the excitability properties of individual neurons" (Malenka, 2002, p. 147).

This all works in a rather amazing, yet straightforward way: Synaptic communication occurs when electrical impulses from the neuron (the pre-synaptic neuron) to its axon(s) achieve sufficient electrical charge (action-potential) to release an electric charge or neuro-transmitting chemical (e.g., glutamate, dopamine, acetylcholine, noradrenaline, or serotonin) that then proceeds across a synaptic gap to a dendrite(s), connected to a different neuron (the post-synaptic neuron). These transmitters play either a facilitating or inhibiting role, creating a kind of binary form of information transmittal, described by Muscolino (2011) as being similar to that used by a computer (Muscolino, 2011). Firing provides a synapse two possible forms of change: functional and structural (Muscolino, 2011). Early repetitions lead to a functional change in the synapse, increasing the length of time taken in releasing the neurotransmitter, and thereby increasing the amount of chemical transported and released. Greater amounts being released in turn increase the likelihood of the post-synaptic neuron firing, making it more likely that the firing will continue the impulse down the memory pattern's neuronal pathway (Muscolino, 2011).

Additional changes, now structural in nature, occur with more repetition, leading to an increase in new synapses being formed, and increasing both the number of connections and the amount of transmitter being passed from the pre-synaptic neuron to the post-synaptic neuron. This further increases the likelihood that the post-synaptic neuron will fire. In time and with repetition these heavily frequented synaptic connections create a well-used pathway and become a part of long-term memory, like "water etching a deeper and deeper pathway into the side of a mountain over a period of time" (Muscolino, 2011, p. 93). Not only are synaptic connections strengthened by greater amounts of transmitter being released through additional firings, however the connections (axons) are in addition fortified, as repeated firings causes an increase in an

insulating material called myelin. Myelin is a fatty sheath which serves the two functions of insulation and acceleration of impulse conduction (e.g., Dangond, 2004).

3.1. Neuroplasticity and education—a cause and effect relationship

Plasticity research shows that different experiences and forms of education lead to different brain structures (e.g., Kolb & Gibb, 2008; Malabou, 2008). For example, an engineer's brain is different than a musician's brain. While they may not think of it in this way, when students choose a discipline as a topic for learning they are making a decision to change their brain in a particular way. In the context of plasticity, then, teaching can be viewed as a conscious means of forming students' brains to be able to operate in a certain manner – e.g., being able to manage a business in dynamic international settings.

3.2. The role of repetition in plasticity—the good news and the bad news

A variety of plasticity outcomes relate to repetition and in many ways, repetition provides a key to understanding plasticity. The development of weights and a priming process further contribute to the importance of repetition. Over time and with experience, a kind of weighting system seems to emerge within and across different synaptic networks. These weights are a function of the degree of use or repetition of firing with large (heavier) weights given to pathways firing more frequently (Martin & Morris, 2002). The brain operates with a preference for conservation and homeostasis, and the weighting system seems to be one of the ways allowing it to operate more efficiently. Less energy is required simply by employing these weights in determining which networks are to be accessed first. The weights can be thought of as "attractors" providing a clear path (in what would otherwise be a chaotic roadway) through trillions of brain connections available for navigation. Until recently it was thought that consistency in these synaptic configurations and defined weights were required for memory retention. More recent studies have shown, paradoxically, that both stability and flexibility are required, and that memory retention is an active process, with synaptic flexibility allowing the brain to retain old learning while experiencing new learning (e.g., Kolb & Gibb, 2008; Loftus, 2003).

Another repetition-related aspect of conservation involves the priming effects of repetition (repetition priming). While the increased strength of synaptic connection caused by repetition increases behavioral performance by giving rapid access to previously used information, it moreover leads to a general reduction in neural activity through its counterpart "repetition suppression," thereby reducing the amount of overall energy needed for the task at hand and ultimately to less thinking (e.g., Garrido et al., 2009; Gotts, Carson, & Martin, 2012). In this way habits result from repetition. Repetition creates heavily tracked neural-pathways that are accessed more readily (repetition priming), while reducing the overall neural activity (repetition suppression), less thinking, and results in the strengthening of the habit.

Plasticity allows change, however one possible form of change is to become more rigid as a consequence of overexposure to repetition and repetitive experiences creating a kind of "plastic paradox" (Doidge, 2007, p. 242). As the brain is developmentally driven by a preference for neurological efficiency, it utilizes the processes of pruning and conditioning to move toward that goal. Information is distributed both within and across the synchronization of the neural networks or ensembles and not accessed via a single connection. When repetition stops or when a neural pathway ceases to be frequented, plasticity results in the pruning away of the unused connections. If connections cease to be used, pruning occurs and the connections are discarded, "freeing resources for connections that matter" and new forms of neural networks (Breznitz & Hemingway, 2012, p. 109).

Hemispherically, plasticity effects from experience-related repetition become evident with age, and have the potential to impact creative abilities. It appears that early in life we rely more on the right hemisphere to view and interpret the new and novel by creating new associations in the form of new neuro-networks of synchronized synaptic connections. With time we acquire experiences, which are stored in the left hemisphere in the form of patterns contained within neuro-networks. With age the previously available patterns are increasingly repeated, and the role of the right hemisphere diminishes (Goldberg, 2006).

While human development initially seems to require imbalance in favor of the right hemisphere for survival, left-sided dominance prevails. Synaptically, the brain develops along lines of consolidation around developed patterns, connections, or experiences to allow one to navigate environments continuously along familiar paths, even though the means or paths used for navigation may not be optimal. Again, this process is driven by the brain's conservation homeostasis.

Another part in this process is played by the corpus callosum, which controls the synaptic communications between the two hemispheres. Here when repetition becomes dominant, a different form of plasticity occurs involving the corpus callosum. While little is known about the corpus callosum, it is believed that it can play the role of both activating and/or inhibiting brain regions (e.g., Bloom & Hynd, 2005; Van der Knaap & van der Ham, 2011). From an evolutionary perspective it seems to have developed to allow the brain to operate more efficiently (i.e., Aboitz & Montiel, 2003). As the role of the left hemisphere increases, the corpus callosum becomes conditioned to inhibit accessing the right hemisphere and aids in the process of pruning or eliminating weak brain connections that aren't frequently activated (e.g., Garrido et al., 2009; Grill-Spector, Henson, & Martin, 2005). In time, as the right hemisphere shrinks, so does the corpus callosum through a process of atrophy (e.g., Fling et al., 2011). With less utilization of, and with more difficult access to the right hemisphere, creativity becomes more difficult and greater reliance is given to the left hemisphere (recursively) and past ways of doing things.

The prejudice toward (or the weights given to) developed patterns – toward mental rigidity – favors a preference for what worked in the past, assuming that it should continue to work in the present and beyond. This creates behavioral tendencies toward less-than-optimization, illustrated by the psychological phenomenon of satisficing (a "good enough" heuristic) and the automaticity (habits) that accompany it (e.g., Breznitz & Hemingway, 2012). We "… stop searching when we find a solution that is good enough. Satisficing, together with partial reinforcement of seemingly 'good enough' solutions, lead to mental rigidity" (Breznitz & Hemingway, 2012, p. 51). The resulting effect on the potential for flexibility or creativity is predictable. "… (A)utomaticity despite being efficient and often useful, precludes innovation and change. It is inappropriate in situations that are different enough from the past situations to require new thinking" (Breznitz & Hemingway, 2012, p. 32).

With this in mind, we now address the question: "How can this neuro-plasticity perspective inform managerial preparation? We address this by examining two different educational methods – teaching-to-repeat (T2R) and teaching-to-vary (T2V).

3.3. Two different approaches to teaching – their plasticity outcomes

T2R and T2V are used here to represent approaches to teaching characterized by quite different degrees of dependence on repetition, both in terms of presentation and content. Differences in what is to be repeated (what is to be learned), can lead to different behaviors, however more importantly to different forms of plasticity. We argue that these differences in plasticity contribute to the gap between what education has provided and what industry is asking for. Borrowing shamelessly from Malabou (2008) we ask "How should business students' brains operate upon finishing their programs of study?"

Traditionally, behavioral criticisms have dominated discussions of methods like T2R. Of special concern is the degree of importance placed on stability and consistency. Teaching-to-repeat represents a popular manifestation of the transmission-based methods associated with passive learning. In this approach, knowledge is viewed as something to be "received" (Belenky, Clinchy, Goldberger, & Tarule, 1986). This assumes that "knowledge" exists in some fixed and finite form, available to be transmitted. The "match" between content given and that produced in examination is used to indicate the degree of learning that has occurred. Sometimes "partial credit" can be earned for content repetition that varies in some minor way from content transmitted, so long as the essence of the truth of transmitted content is present in the repetition. O'Donovan (2010) has likened this educational approach to "filling a pail."

Response stability is not just desirable; it is essential to the effectiveness of T2R. So it is not surprising to find that the relationship between rote response and educational success begins in the early grades where much focus is on imparting basic skill sets and in areas where subject domains are relatively stable (e.g., reading, writing and arithmetic). As consensus and consistency (a form of stability) are fundamental in communication, the rote learning and memorization aspects of T2R can be both effective and efficient in preparing students to communicate using common precepts. Repetition in addition can increase speed and consistency in response, so this method continues to offer desired educational outcomes later when the educational goal involves the consistent and/or rapid performance of a task or application of a skill set, as when reaction time and lack of variance contribute positively to the quality of the outcome itself. As long as there is a stable relationship between educational input and desired outcomes, repetition can provide an effective means for learning.

Any use of repetition as a tool for learning involves several biases or assumptions, some perhaps more obvious than others. These include implicit biases in favor of stability, with an emphasis on familiarity, conformity, efficiency over effectiveness, and an assumption that "right answers" to business questions exist and have value unrelated to the questions for which they were created or the circumstances (decontextualized) that caused those questions to be asked. While such criticisms have been made, however, they have been largely associated with issues relating to content. From the perspective provided by the desirability of thinking agility, however, more fundamental issues are being overlooked.

Lost to response efficiency in the T2R experience is the development of students' own questioning skills and the ability to use such skills in producing their own answers. Further lost is the student's ability to judge when to deviate from past methods (or utilize divergent thinking), or to know how to develop a unique perspective (e.g., Gibson, Folley, & Park, 2009). These are the very skills needed when businesses confront situations that vary from past experience in significant ways (e.g., Finch, Nadeau, & O'Reilly, 2013). Pause for a moment to consider the speed of change in competition globally, with change coming from every angle and direction. How helpful would the T2R method be as preparation for management decision-making in this scenario?

Further, our understanding of neuroplasticity now reveals that through its "answers" perspective on learning, T2R conditions the brain to operate using established synaptic weights based upon past behaviors, thereby further increasing those weights and strengthening those connections while establishing a preference or disposition for ready-made patterns over developing new ones. This process serves to create a closed posture or perspective, distancing students and/or managers prepared through use of such methods from recognition of the changes occurring around them. Quite simply, T2R-like methods condition students' brains to operate in a more rigid manner. It should be no surprise when they bring this characteristic with them into the workplace.

3.4. Education for change: fluid intelligence and teaching-to-vary (T2V)

From both neurological and behavioral perspectives, the repetition-related effects of a T2R approach not only fail to prepare managers for effective decision-making, it actually works against the development of the very capabilities needed for successful management practice in changing environments.

It must be noted that repetition is involved in all forms of learning. With a different instructional design, however, different outcomes are possible. What is repeated or practiced can lead to different forms of plasticity. T2R leads to a more functional type of plasticity, emphasizing neural efficiency or the development of what Garlick (2002) called "crystallized intelligence." This advances skill levels involved in continuing the utilization of known forms of representation (e.g., knowledge, preferred practice, routines). The proposed alternative, T2V, is designed to foster the type of plasticity associated with "fluid intelligence" (g-intelligence or the g-factor), encouraging the creation of new neural patterns and neural-networks of the sort that orient the brain toward more fluid conceptualization and reasoning.

The goal of Teaching-to-vary (T2V) is to move the focus of business education away from an emphasis on transmission of data, and toward development of agile thinking skills - from content retention toward development of an appreciation for, and ability to practice variability in experience, questioning, thought, and analysis. T2V methods involve the use of full-brain methodologies, designed to work toward, not against, improved hemispheric balance and toward, not away from, increasing plasticity of the type required for development of more original and adaptive decision-making capabilities.

Before examining T2V methods designed to foster variability in thinking, we must first recognize that there are psychological and behavioral obstacles that work against it.

4. Obstacles to agility and how to overcome them

In T2V, educational emphasis on content replication is replaced by an emphasis on the development and application of skills needed move away from old paths, to vary. While deviation from the status quo or norms has been shown to create dissonance (psychological discomfort), repetition can equate with acceptance and conformity. Through repetition, norms become routinized and in the process normalized or comfortable, no longer requiring any thought or critical consideration. In taking an agility perspective, it is the discomfort associated with varying that should be normalized. As the tolerance for varying is increased, psychological space for varied thinking and change is opened, engaging our plasticity.

Further, important components of educational environments may have formed in support of the status quo. In designing T2V methods, these must be recognized and addressed. To this end, we offer brief discussions of the role of "the familiar; " key forms of fixedness that serve to oppose variation; and rewards in a T2V environment.

4.1. The role of the familiar

"The familiar" (a byproduct of repetition) is both pivotal and paradoxical in T2V, providing both the strongest resistance to T2V, but also providing the best and most automatic "early warning signal" that an opportunity to employ agile thinking in a situation exists. The comfort in following familiar patterns of choice provides evidence that the familiar is in control; that variation from some "sacred grove" has not occurred; that some path created long ago continues to be followed blindly (Foss, 1890). At the same time, the level of anxiety produced in moving outside one's own comfort zone can provide one good clue that the pull of the familiar is being challenged, "If you're comfortable, you're likely stuck in the groove of old thought. Therefore, being comfortable needs to become problematic" (Schwartz, 2011, p. 2).

Still leaving the comfortable zones of old behaviors is not easy and is often perceived as threatening. "We create excuses or justifications to either procrastinate or utterly avoid the discomfort of new thinking and new behavior" (Schwartz, 2011, p. 2). The apparent social stigma of being seen as different, outside the group, further reinforces the status of the familiar. In consequence, familiar approaches are established as preferred neurologically, psychologically and socially.

4.2. Is the familiar the only obstacle to be accommodated in T2V?

Any aspect of the educational environment that prevents questioning or that constrains the development or exploration of additional options, alternatives or approaches may serve as an obstacle and should be examined for its effects on T2V (e.g., Hill, McGinnis, & Cromartie, 2007). All forms of fixedness or mental rigidness can be seen to be manifestations of the familiar and unless accommodated, may act against successful T2V implementation in the classroom. For example:

4.2.1. Functional fixedness

This phenomenon is manifested when prior learning about an item's original intended use (e.g., a song, a coffee cup) impedes subsequent thinking about its other possible uses (e.g., Duncker, 1945). Younger children have been shown to be more immune to these affects than older children (e.g., German & Defeyter, 2000), suggesting that younger children rely more on their brain's right hemisphere and less on repetition of past patterns. With age this reliance shifts to the left hemisphere, in correlation with starting school. Manifestations of functional fixedness need to be identified before its grip can be loosened. Exercises can be designed to encourage students to come up with different functions for objects. Through practice, varying thought can reverse the functional fixedness effects.

4.2.2. Exemplar-based fixation

This results when the use of an example serves to restrict subsequent thinking to the production of solutions resembling or imitating the example given (Jansson & Smith, 1991). Linsey et al. (2010) suggest that detrimental fixation effects from this practice can be mitigated by using multiple analogies, providing explicit de-fixation instructions, or by providing multiple

representations of the problem or categories of solutions. While good teaching typically is associated with providing good examples to facilitate improved communication, here we see the need to accommodate an additional potentially negative effect.

4.2.3. Process-based fixation

This seems to originate from the manner in which ideas are generated by learners and whether feedback is given during or after completion. Dow et al. (2010, p. 16) found that delay (parallel processing) in giving feedback helps learners to reflect and to be more open to alternatives, "… while readily available, immediate [serial processing] feedback can serve as a crutch that discourages building a deep understanding [while promoting refinement of an idea even if the idea is suboptimal] …" Accordingly normalizing the discomfort from not having immediate feedback can lead to better outcomes by encouraging that more possibilities be considered. Ambiguity leads to more thinking, allowing for increased varying, and promoting agile thought in the process. Further, serial feedback may, have the effect of channeling the thinking of those (students, employees) working on the problem through the biases of those providing the feedback. In encouraging agile thinking, that should be avoided.

4.2.4. Expert fixedness

When the relationship between expertise and adaptability (e.g., Canas, Quesada, Antoli, & Fajardo, 2003; Lewandowsky, Little, & Kalish, 2007) are studied, findings generally confirm an inverse relationship between expertise and adaptability – as expertise increases, adaptability decreases (e.g., Dane, 2010). An increased awareness of areas of knowledge beyond one's own specializations has been shown to increase the likelihood of consideration and appreciation for a wider variety of problem-solving approaches. Hargadon, 2006 (p. 209) found that "Having one foot outside your world means you can be less beholden to the ties that would otherwise bind and blind you in that world."

The neurological perspective of plasticity sheds additional light on some of the consequences of various preferred elements typically associated with traditional, T2R teaching methods. These include viewing functionality singularly; using examples for clearer communications purposes; providing serial feedback to alleviate students' anxiety while leading them to a preferred answer; and developing an expertise in only one area of knowledge. Each of these seem to be predicated on the type of repetition that leads to entrenched narrower neuro-networks, producing increased rigidity and fixed thinking. In contrast, using varying techniques in teaching facilities a neurology of agility created through wider neuro-networks (ensembles utilizing different synchrony) that are constantly under development, open to new connections.

5. Beyond the barriers – the finish line as a moving target

In T2V, barriers need to be identified, recognized, and must be actively worked against. The skills needed to this, to move beyond the familiar and to vary, can and must be taught. Throughout this process, the discomfort involved in moving away from the familiar qua familiar should be viewed as the signal to begin and as a resource to produce the energy for developing new ways of doing things. The next step in actively engaging the familiar as called for in T2V implementation is to recognize and accommodate the critical role of rewards and reinforcement. Original thought and application – varying – is to be encouraged and reinforcement techniques reflect this. The following are offered in illustration.

5.1. Rewards and motivation-aren't the medals handed out at the end of the race?

A description of the brain's reward circuit must be included in any discussion of learning processes. Basal ganglia promote the exploration (variability) or exploitation (repetition) of ideas and behaviors (Stahlman, Leising, Garlick, & Blaisdell, 2013). It is believed that the basal ganglia regulate the optimal control of action via the dopamine reward system (Graybiel, 2005). Both motivation and the magnitude and probability of reward are involved in the operation of the system (Graybiel, 2005). This enables the dopamine-containing neurons to tune their range of sensitivity, and to exhibit context-dependence in dopamine release (Gabora & Ranjan, 2013). A reduction in reward expectations increases variation in behavior. Once the pattern of rewarding becomes known, dopamine release declines and variability decreases (Stahlman et al., 2013). So there is an inverse relationship between expected rewards and variation in behavior or thought. Uncertainty in reward produces a tension state, which in turn encourages variability.

Cherot, Jones, and Neuringer (1996) found temporal negative effects result from rewards. The proximity of the reward has an "attractive pull" in opposition to variability. With the approach of the reward, the perceived need for the "varying" in thinking decreases and ultimately, stops. The increasing proximity of rewards, acts to de-motivate and leads to satisficing (i.e., its good enough).

Other studies have shown rewards to have negative effects on variability in various types of activities. For example, Schwartz (1982) found that: 1) rewards within a classroom setting can be counterproductive to variability and can cause a negative effect on the intrinsic motivation; 2) activities that are already intrinsically rewarding need not be externally rewarded; and 3) rewards may be decreasingly used to encourage activities that are increasingly intrinsically interesting. This suggests that rewards might be used to encourage engagement (extrinsic motivation) with an originally negatively perceived task until a more positive disposition develops (intrinsic motivation). Once this development occurs, the rewards should be discontinued.

5.2. Differential reinforcement effects—is this a track event or a tennis match?

In sports as in business strategy, varying one's responses to an opponent's action may be critical to winning. Having a repertoire of maneuvers/techniques and the ability to use them in varying combinations and/or sequences is required to outmaneuver one's opponent. Harding, Wacker, Berg, Rick, and Lee (2004) report findings from a series of sport-based studies showing that differential reinforcement procedures can be used to improve this type of variation in performance. Their investigation found that reinforcement of varying techniques during practice led to an increase in response variability in play, and moreover to the extinction of repetitive behaviors.

5.3. Potential age-related differences in the effect of rewards on extinguishing varied behaviors – old dogs, new tricks?

Lopatto et al. (1998) examined potential age-related differences in cautiousness, stereotypy, and variability using continuous versus intermittent reinforcement. They found that: (1) continuous reinforcement led to higher levels of stereotypy than intermittent reinforcement for both college students and adults, (2) intermittent reinforcement revealed an age difference, where adults showed greater levels of stereotypy than college students, and (3) utilizing intermittent (differential) reinforcement led to learning varied response patterns for both groups.

These results, together with the findings of Cherot et al. (1996) suggest that varying responses are more likely to occur with varied reinforcement, and as the reinforcement event approaches, the "varying" will decrease. In contrast, stereotypy or repeated response patterns develop with regular or continuous reinforcement (e.g., serial feedback, expected grades). So it would appear that Nueringer was right when he said that "variability is controlled by its consequences," and that "repeating and varying, in part, are learned skills under the control of reinforcing consequences" (Nueringer, 2004, p. 891).

6. Conclusions

This research advances the argument that practitioner complaints about the sorts of deficiencies in skills and competencies found in business students may result at least in part from what we call T2R. Behaviors taught in the classroom are being felt in the workplace. In contrast to the structured educational environment, managers work in an environment that is characteristically variable: a "messy, fluxing, chaotic world of competing demands …" (Chia, 2005, p. 1092). To effectively prepare managers to function productively in this type situation, we offer an agile thinking perspective, employing what we call T2V, a pedagogy based upon an understanding of neuroplasticity and specifically designed to develop variability in thought.

Neuroscience has shown that the brain is plastic, and that different forms of plasticity result from different experience and practice. In T2V, we incorporate the practice of varying in pursuit of different form of plasticity than that offered via T2R. We argue that this type of plasticity allows for more originality and flexibility in thought and approach along with practice can develop an inclination or predisposition towards change. The agility perspective presented suggests that in educating managers for today and tomorrow, we move past T2R, beyond critical thinking, to consider a wider spectrum of alternative thinking approaches. This research moreover asks educators to recognize the full impact of educational methods and to ask themselves: What type of plasticity do we want? What type of plasticity are we fostering in the classroom and ultimately, beyond?

Teaching-to-vary requires thought in reshaping reward systems, for students as well as faculty, away from the patterns adopted as a part of a T2R model. Too often these act to actively discourage T2V methods and the development of more agile thinking. It requires recognition and avoidance of various forms of mental fixedness. In T2V, the back and forth of conversation replaces the lecture. The ability to ask a good question becomes more important than the ability to recite answers provided by others. Questions reveal themselves to have the potential to create new and varied approaches, so in T2V questioning is valued and fostered behavior. In this approach students' original thoughts generated through their unique questioning skills are rewarded.

Developing agility is not without work. It requires an understanding that embracing difference is at the very heart of T2V (Hill, 2010). An environment that fosters students' inclination or disposition towards change, (i.e., a state of agility in thought) can be created in the classroom as a form of "active learning" accomplished through a focus on varying. This requires creating conditions that both incorporate and normalize the psychological discomfort involved in varying, and restructuring motivations and rewards to account for this.

We recognize the existence of difficulties implicit in adopting T2V methodologies. To mention just a few, consider that students experienced in T2R are conditioned to its expectations and reward systems. They may find T2V techniques uncomfortable and time-consuming, at least at the outset, and their teaching evaluations will likely reflect their objection to the use of unfamiliar methods. Some degree of "institutional buy-in" is helpful along with some degree of change in faculty preparation. We are all subject to the hold of the familiar, and this might manifest itself in the use of our own T2R learning experiences as prototypical of teaching.

While neurological and psychological research provide a strong case for T2V, methodologies that embrace the T2V model are less common—especially at the post-secondary level. One reason may be that traditional Ph.D. programs are designed to encourage students to think deeply about their areas of specialization, rather than to consider issues associated with the transmission of knowledge. These programs are designed to develop graduates that can produce research to advance their

field of study, not to produce outstanding teachers. Consequently, courses addressing post-secondary teaching methodologies are rare in doctoral programs and doctoral students often are left to develop their own teaching approaches, frequently modeling their "favorite" professors. While this expediency is understandable, it may serve to perpetuate T2R methods. Offering courses encouraging research, practice and discussion of differing ways of teaching business as a normal part of doctoral programs might serve to overcome any bias toward T2R.

Then there is the persuasive and attractive structure favoring T2R provided by the publishing industry: ready-made teaching materials, prepared power-point lectures, test banks filled with objective questions, etc., all electronically loadable for passive consumption and content-consistent response. Even offered are electronically provided, auto-graded "open ended written" questions and exercises, which, of course, evaluate answers through pre-assigned key-word searches and matching. Finally it must be cautioned that T2R is often the favored option for the conduct of large-sized business school classes, valued by institutions and government funding agencies for their cost-saving and revenue-producing possibilities.

In contrast, and as illustration of the values offered through implementation of T2V and development of more agile business thinkers, we point to what Dyer, Gregersen, and Christensen (2009) in "The Innovator's DNA" call the five important "discovery" skills of innovators: associating (creating unique associations), questioning (challenging the status quo), observing (becoming more sensitive to change as it is occurring), experimenting (trying new approaches), and networking (expanding one's sources of information). Development of these skills lies at the heart of T2V. Their use in practice demonstrates the type of agile thinking that practitioners seek, however don't find in many of today's business school graduates.

6.1. Directions for future research

Much additional research is needed to provide a full understanding of the underpinnings of thinking agility and the methods that might be used to facilitate its development in educational settings. For example, we might ask: Would a more organic classroom setting facilitate students' agile thinking skills? What differences might be offered between facilitating agility in the classroom or within an organizational setting? What electronic applications are possible? What types of educator-preparation might prove the most useful? What is the relationship between agile thinking at the individual level and strategic agility at the organizational level? And, how can agility be sustained?

We invite our colleagues to help in expanding and refining our understanding of this approach, its applications, and implications. Perhaps our discussions will help us to apply more thinking agility to the current state of business and management education and might encourage it too to become more open and flexible. Possibly our questions and our discussions can help to improve the degree of practitioner satisfaction offered by the preparation of business graduates.

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