Neuroscientism, the neuroscience of learning

An integrative review and implications for learning and development in the workplace

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Abstract

Purpose – Although the field of neuroscience has evolved dramatically, little research has attempted to conceptualize the impact of neuroscience on the field of human resource development (HRD). The purpose of this study is an integrative review of the influential relationship between neuroscience and workplace learning including applicable implications for HRD research and practice.

Design/methodology/approach – By reviewing 93 studies on neuroscience and brain-based learning published between 1995 and 2017, the authors synthesized their findings.

Findings – This study discusses the basic concepts of neuroscience such as the structure and functions of the brain, neuroscientific findings about memory and cognition, the effect of neural transmitters on memory and cognition and the neuroscience of learning. This study also illustrates brain-based learning styles affecting learning and describes various neuroscientific learning principles and models that can be applied to practical planning and the delivery of workplace learning and HRD activities.

Originality/value – This study concludes with brain-based learning principles called neuroscientism compared with traditional learning theories. It also includes several brain-based learning cases from workplace settings and implications for future research and further HRD practices.

Keywords Neuroscience, Human resource development, Workplace learning, An integrative review, Brain-based learning, Neuroscientism

Paper type Research paper

Introduction

Schwab (2017) explained the Fourth Industrial Revolution as an unprecedented technological evolution, which is blurring the lines between the physical, digital and biological spheres. The emergence of Industry 4.0, the current trend of automation and data exchange in manufacturing technologies, has had a considerable impact on various fields from business and education to many other areas in our daily lives. Human resource
development (HRD) has also been affected by this trend (Hopkins, 2017; Martindale, 2014). In Industry 4.0, neuroscience, the study of human cognition and brain functions (Schwartz-Hebron, 2012), has created a new pathway to rethink HRD and human resource management (HRM) initiatives (Brandt, 2000; Dolan, 2002). Hodgkinson and Healey (2014, p. 766) have strongly advocated adopting “a new, biologically rooted, subfield that aims to map neural mechanisms as the prime causes of organizational behavior”.

In the fields of HRD and HRM, many organizations have already applied neuroscientific findings to manage and improve employee performance (Martindale, 2014). For example, Rock and Ringleb (2013) from the NeuroLeadership Institute proposed the Status, Certainty, Autonomy, Relatedness, and Fairness (SCARF) model to explain the impact of positive and negative emotions on people’s behavior. Another example is applying neuroscientific findings to effectively conduct performance appraisal tasks with an open mind. Some companies have also adopted physical exercise sessions during training courses to enhance brain functions and activity levels. It is now common to use neuroscientific findings to coach executives in coping with stress in many organizations (Brann, 2017). These examples illustrate how neuroscience has penetrated many aspects of the HRD and HRM fields.

The influence of neuroscience on HRD activities (e.g. training and development, organization development) has been explored by many researchers and at conferences such as the Association for Talent Development since the early 2000s. However, little research has attempted to understand and conceptualize the relationship and impact of neuroscience on the HRD field, particularly workplace learning. Rather, these studies have mostly investigated the crossover between neuroscience and HRD focusing on a limited scope of research, such as leadership development and activity-level training interventions (Bossons et al., 2015; Lou, 2008). Therefore, it is meaningful to provide an integrative review of the connection between neuroscience and workplace learning and consider more viable and applicable implications for HRD researchers and practitioners.

It is also important to specify how HRD researchers can apply the findings from neuroscience studies to construct a new research agenda in academia and improve the practices of HRD in the workplace. The research questions guiding this study are as follows:

**RQ1.** What are the basic structure and functions of the brain?

**RQ2.** How does neuroscience explain cognitive and affective learning?

**RQ3.** What do theories and models suggest about the principles for brain-based learning?

**RQ4.** What are important learning strategies for brain-based learning in the workplace?

**RQ5.** What are some cases demonstrating organizational applications of neuroscience for workplace learning?

**RQ6.** What are the implications of the neuroscience of learning for HRD research and practice?

To address these research questions, we must first discuss the basic concepts of neuroscience such as the structure of the brain and functions of the major brain parts, neuroscientific findings about memory and cognition, hormone effect on learning and the neuroscience of learning focusing on cognitive and affective learning. We then illustrate brain-based learning styles to understand how different learning styles affect individual learning. Based on an in-depth analysis of recent neuroscientific research findings, we then propose brain-based learning principles and models that can be applied to practical planning and delivery of
workplace learning in an effective way. We also provide examples of how the brain-based learning principles have been applied in organizations. Last, we provide implications of the neuroscience of workplace learning for HRD research and practice.

**Methods**

To conduct an integrative literature review, we adopted Torraco’s (2005, 2016) method, Callahan’s (2010) guidelines and suggestions from Lipsey and Wilson’s (2001) study to search for relevant studies. These methods allowed us to identify the location of articles, search the articles, select the types of articles and criteria for article selection and index the information. These methods have helped researchers explore and establish new directions for emerging research studies in many disciplines (Yorks, 2008).

Before searching for relevant literature, we set inclusion and exclusion criteria to limit the scope of the research, such as the topics and keywords, publication periods, types of publications and research areas. As for the inclusion criteria, we searched the literature using various keywords such as neuroscience, brain functions, principle of memory, principle of cognition, brain hormone functions, affective learning, brain-based learning, brain-based learning models, brain-based learning principles, brain-based learning strategies and workplace learning. We selected the multiple keywords to discover comprehensive literature and publications related to both neuroscience and workplace learning. Using these key words, we conducted a literature review using multiple databases including Academic Search Complete, Business Source Complete, Educational Full Text, ERIC, Google Scholar and PsycARTICLES. Except for books, white papers and dissertations, research articles used for this study were from journals including Contemporary Educational Psychology, Educational Leadership, British Journal of Educational Psychology, Human Resource Development Quarterly, Human Resource Development Review, European Journal of Education, European Journal of Training and Development and Psychological Science.

We followed four steps to review the literature. First, our initial search yielded 2,420 studies based on three criteria:

- scholarly articles in peer-reviewed journals, dissertations, books or book chapters and white papers;
- studies with an integrative and/or comprehensive literature review; and
- studies containing workplace and neuroscience cases.

We did not include studies that focused on pure scientific brain research. Hence, we excluded the brain research from health and medical perspectives, such as animal experiments, brain diseases, medical care/cure, neural imaging, neural networks, neurobiology and sleeping, which were not relevant to the purpose of this research. Second, out of the 2,420 initial research studies, 93 documents published between 1995 and 2017 were included in our final review. We regarded the year 1995 as the starting point of our literature review because the term brain-based learning was introduced in 1995 (Jensen, 1995). The final review sample was 93 studies including 44 articles, 44 books/book chapters, one dissertation and four white papers, all of which contained highly related information for our research. Third, we reviewed the 93 documents and coded them by author(s), year published, title, journal/book name and key themes based on the first five research questions. In addition, we synthesized our findings using the following four categories:

- the structure and functions of the brain;
- cognitive and affective learning in neuroscience;
brain-based learning theories and models; and

strategies.

Fourth, we identified several cases that demonstrate how organizations apply neuroscience-based learning strategies in their practices. Table I presents the literature review process in this study.

Findings

From our extensive literature review, study findings are organized in terms of structure and functions of the brain, cognitive findings about brain-based learning and theories and models of brain-based learning. From the findings, we propose our brain-based learning model called neuroscientism along with its detailed information including emotion and learning, motivation and learning, sensory learning, attention and learning and reflective learning. Last, we provide several cases for brain-based learning taking place in the workplace.

Structure and functions of the brain

Neuroscience researchers have primarily studied how the brain is structured and the unique function of each brain part (Bresciani Ludvik, 2016). However, recent studies have changed the direction of the research by viewing the human brain as a neural network or computerized system to reveal the complex nature of neural signaling patterns and human cognition (Schwartz-Hebron, 2012). This approach has helped researchers better understand the human brain as a holistic system and specified more feasible methods to unleash human cognitive capabilities and improve learning effectiveness.

The structure of brain. The human brain is the chief control tower of the human nervous system, largely consisting of three parts: cerebrum, brainstem and cerebellum. The brain weighs around 1.2-1.4 kg (2.6-3.1 lbs.), which comprises about 2 per cent of the adult body

<table>
<thead>
<tr>
<th>Steps</th>
<th>Activities</th>
<th>Outcomes</th>
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<tbody>
<tr>
<td>1</td>
<td>Search</td>
<td>Using keywords and mixed terms (neuroscience, brain functions, principle of memory, principle of cognition, brain hormone functions, affective learning, brain-based learning, brain-based learning models, brain-based learning principles, brain-based learning strategies and workplace learning) Academic Search Complete, Business Source Complete, Educational Full Text, ERIC, Google Scholar and PsycARTICLES 2,420 documents</td>
</tr>
<tr>
<td>2</td>
<td>Screening and selection</td>
<td>44 articles 44 books/book chapters 1 dissertation 4 white papers 93 documents</td>
</tr>
<tr>
<td>3</td>
<td>Analysis and synthesis</td>
<td>The structure and functions of the brain Cognitive and affective learning in neuroscience Brain-based learning theories, models and strategies Answers for RQ1, RQ2, RQ3 and RQ4</td>
</tr>
<tr>
<td>4</td>
<td>Identification</td>
<td>Case studies in organizations Six cases (one in Japan, three in Korea and two in USA)</td>
</tr>
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Table I. Literature review process
weight, but it takes in 15 per cent of the blood and 20~25 per cent oxygen in an adult body (Bigos et al., 2015). The major functional structure of the brain includes the cerebral cortex, the midbrain, the hindbrain, the insula and the limbic system (Toga, 2013). As seen in Figure 1, the outer cerebral cortex is composed of the frontal lobe (accounts for logical thinking, problem-solving, critical thinking, creative thinking, decision-making and integration of memory), the parietal lobe (performs physical sensing and balance, spatial sensing and calculation), the occipital lobe (responsible for visual senses) and the temporal lobe (processes auditory senses and language memory). Figure 2 illustrates the limbic system and subcortex structure of the human brain.

As a core function of the human brain, the limbic system, located between the border of the cerebral cortex and the hypothalamus, controls fear, emotions, motivation, learning and memory and involves important cognitive processes of the brain (Phan et al., 2002). The limbic system includes various subparts: the amygdala, hippocampus, cingulate cortex, hypothalamus and thalamus. Table II provides more detailed descriptions about the location and functions of the major parts of the brain related to learning and emotion.

**Memory and cognition.** One of the most fundamental foci of neuroscience is studying human cognition and memorization processes. Neuroscientists define a memory process as the electrical and chemical stimulus and response pattern occurring between the neurons through a synaptic transmission process (Freund et al., 2003; Seung, 2012). The human brain is composed of about 100 billion neurons and 100 trillion synapses (Chageux, 1985). The basic structure of a neuron consists of the nucleus, dendrites, axons and axon terminals.
neuron can have up to 8,000-15,000 synaptic connections with other neurons. When we perceive some sensory stimuli through our senses, it creates an electrical pulse (5-2,000 Hz) and some neurotransmitters in neurons to activate receptors across the synapses. If the process of sensory stimuli is repeated, the connections between the neurons are strengthened and eventually create neural signaling patterns that are assumed to store the sensory information, eventually resulting in memory (Lynch, 2004). Ultimately, memory is the outcome of information exchange and communication processes between the brain cells. Neurotransmission is an important brain function to form memory, emotion and cognitive patterns in humans (Klaiber, 2001). Figure 3 illustrates the process of neural signaling to compose a memory.

**Neuroplasticity.** Neuroscientists initially believed that the human brain cannot be altered. However, since the late twentieth century, some scholars have found that the human brain can change even through adulthood (Livingston, 1966; Rakic, 2002; Taupin, 2006). Neuroplasticity is the brain’s capacity to form new neural connections throughout the life span (Young and Tolentino, 2011). Neuroplasticity occurs due to changes in various external

<table>
<thead>
<tr>
<th>Brain parts</th>
<th>Location</th>
<th>Functions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amygdala</td>
<td>Limbic system</td>
<td>Attention, fear, emotions</td>
</tr>
<tr>
<td>Hippocampus</td>
<td>Limbic system</td>
<td>Spatial memory, long-term memory</td>
</tr>
<tr>
<td>Prefrontal cortex</td>
<td>Frontal lobe</td>
<td>Higher cognitive functions, executive functions, decision-making</td>
</tr>
<tr>
<td>Thalamus</td>
<td>Limbic system</td>
<td>Physical security, regulation of consciousness and sleep</td>
</tr>
<tr>
<td>Hypothalamus</td>
<td>Limbic system</td>
<td>Feelings of rage, aggression, hunger and thirst</td>
</tr>
<tr>
<td>Basal ganglia</td>
<td>Subcortex</td>
<td>Relay of motor and sensory signals to the cerebral cortex</td>
</tr>
<tr>
<td>Insula</td>
<td>Subcortex</td>
<td>Voluntary motor control, procedural learning, cognitive and emotional functions</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Control of body states, pain perception, social engagement, empathy, emotions</td>
</tr>
</tbody>
</table>

**Table II.** Functions of brain parts related to learning and emotion

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**Sources:** McCormick (2013)
factors such as environmental, interpersonal and relational or internal factors like a change in neural processes. During these change processes, the human brain may undergo synaptic pruning, delete certain neural networks due to the lack of usage and solidify frequently used ones (Buonomano and Merzenich, 1998). The notion of the brain's plasticity is critical for learning, as it provides important clues to design learning activities that are appropriate for composing new neural patterns.

Learning scientists have also sought to identify optimal learning environments to facilitate better neural patterning processes for learning. Learning plays a pivotal role in the course of altering neural connections. For instance, London taxi drivers have a relatively larger hippocampus compared with commuting drivers because they have gone through repetitive learning processes to efficiently navigate through complicated London streets causing them to use more complex spatial information in the hippocampus (Doidge, 2007). These illustrations reveal that neuroplasticity is a two-way mechanism affecting and are affected by external human learning processes.

Neural hormones affecting cognition and learning. The human brain is a complex nerve system influenced by neural hormones (or called transmitters). Most brain functions related to cognition and learning are particularly influenced by certain types of hormones traveling through the human central and peripheral nervous system (Jung, 2011). For example, cortisol is a representative neural hormone negatively affecting cognition and neural information processes. In contrast, serotonin is a neural hormone that positively affects cognition and learning by regulating mood and several physiological needs such as appetite, sleep and sexual desire (Lucki, 1998). Table III presents a detailed illustration of the functions of different types of neural hormones.

### The neuroscience of cognitive learning

**Cognitive learning.** Many theories and principles of cognitive learning have been developed based on research findings in the brain functions and capacity. One important concept in cognitive learning is a schema (schemata), which refers to the memory structure to store generic information in the brain (Rumelhart, 1980). That is, a schema is the consequence of experiences and accumulated knowledge, so each person's schema is unique because people

<table>
<thead>
<tr>
<th>Hormones</th>
<th>Roles and functions</th>
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<tbody>
<tr>
<td>Adrenaline</td>
<td>Emitted when one encounters fear or tension</td>
</tr>
<tr>
<td></td>
<td>Produces toxic materials, active oxygen radicals</td>
</tr>
<tr>
<td></td>
<td>Increases the heart rate and blood pressure</td>
</tr>
<tr>
<td></td>
<td>When high in adrenaline, one can become aggressive or offensive</td>
</tr>
<tr>
<td>Noradrenaline</td>
<td>Plays a role in mood disorders such as manic depression</td>
</tr>
<tr>
<td></td>
<td>Causes attentiveness, sleeping, dreaming and learning</td>
</tr>
<tr>
<td></td>
<td>Accompanied with anger and rage</td>
</tr>
<tr>
<td>Dopamine</td>
<td>Increases strength of the heart and improves blood flow to the kidneys</td>
</tr>
<tr>
<td></td>
<td>Controls movement and emotional responses</td>
</tr>
<tr>
<td></td>
<td>Monitors the brain's reward and pleasure mechanism</td>
</tr>
<tr>
<td>Serotonin</td>
<td>Regulates anxiety, happiness and mood</td>
</tr>
<tr>
<td></td>
<td>Regulates social behavior, appetite and digestion, sleep and memory</td>
</tr>
<tr>
<td>Cortisol</td>
<td>Low serotonin can causes depression</td>
</tr>
<tr>
<td></td>
<td>Increased in stress situations</td>
</tr>
<tr>
<td></td>
<td>Reduces cognitive and memory functions</td>
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**Sources:** Adapted from Jung (2011)
have different experiences across their life spans. Given that learners’ schemata are distinctive, how people learn and interpret information varies. Although not precisely scientific, the notion of schemata describes how memory is stored in our brain cells.

Another theory of cognitive learning, cognitive load theory, elucidates that learners are overwhelmed when they are confronted with complex tasks or an excessive amount of information beyond their brain’s capacity (or working memory) (Paas et al., 2004; Sweller, 1988). Typically, three types of cognitive load are possible (DeLeeuw and Mayer, 2008). First, extraneous cognitive load occurs when information presented to learners is ineffective (e.g., excessive amount of information, or redundant or confronting information is presented simultaneously). Second, intrinsic cognitive load occurs when the structure and information of the learning materials are inherently complex. Finally, the germane cognitive load refers to the construction of schemas through dedicated mental resources and automation of the schemas. Because cognitive overload may inhibit efficiency in learning, material developers should attempt to reduce cognitive load when instruction is designed and delivered. Examples include considering the attention span in instructional delivery and chunking of learning content.

The concept of framing illustrates the strong cognitive mechanism of our brain in the cognitive process of decision-making. Framing explains that the way a problem is stated influences the results of decision-making. According to Thaler and Sunstein (2008), there are two systems in the thinking process: the automatic system and the reflective system. The automatic system is characterized by a fast, effortless, instinctive and unconscious thinking process, whereas the reflective system is a slower, more deliberate, rational, deductive and self-aware thinking process. Thaler and Sunstein (2008) explained that most nudges (a kind of frame technique) are designed to target the automatic system for unconscious behaviors. This implies that, depending on the types and needs of decision-making, the presentation of a problem in a meeting or instructional situation should be carefully designed for effective cognitive processing.

Learning through a self-regulated process and metacognition are also important concepts related to the neuroscience of cognitive learning. For self-regulation, cognitive and attention regulation is related to a wide spectrum of brain functions such as the hippocampus, amygdala, temporoparietal junction, insula, posterior cingulate cortex and medial prefrontal cortex (Bresciani Ludvik et al., 2016). Metacognition, the so-called thinking about thinking process, refers to individuals’ awareness of thinking and self-regulatory behavior (Driscoll, 2005). Unlike children, adults learn better when learning is under their control (Knowles et al., 2005); hence, they must be allowed to monitor and control their own learning process. The demand for active metacognition has rapidly increased in the workplace, so employees can better perform various tasks involving problem-solving and decision-making; thus, the application of neuroscientific findings for developing metacognition and self-regulated learning has become a critical consideration in devising training and development initiatives.

Brain-based learning styles. People learn differently, so there is no single instructional method that best satisfies all learners (Merriam et al., 2007). For this reason, there have been many attempts to identify learning styles. Barbe et al. (1979) explained that learning modalities could be categorized into visual, auditory, kinesthetic or a combination of the modalities. They pointed out that the strength of each learner’s modality should be considered for effective learning. For example, the Swassing–Barbe Modality Index is a scale used for assessing an individual’s learning modality (Barbe et al., 1979). Another simple typology is based on left and right brain styles of learning. Strong left brain learners are more logical, abstract, mathematical, analytical and objective, whereas right brain learners tend to be more intuitive, thoughtful, creative and artistic. Based on this typology,
McCarthy (1987) proposed the 4MAT system specifying four types of learners (i.e. innovative, analytic, common sense and dynamic learners) to ensure that learners fully use both the left and the right brain.

Based on his experiential learning model, Kolb (1984) proposed another learning style incorporating neuroscientific concepts focusing on four learning styles. As illustrated in Figure 4, the experiential learning model consists of four modes in the learning cycle: abstract conceptualization (AC), reflective observation (RO), concrete experience (CE) and active experimentation (AE). According to Kolb (1984), the four modes of learning are mutually dependent and influence each other systematically and systemically.

Based on Kolb’s experiential learning model, Lim (2016) explained that each learning cycle of the model is well matched with different functional areas of the brain (Table IV).

Learning styles can also be inferred by analyzing the four components of the experiential learning cycle, including convergence, divergence, assimilation and accommodation (Kolb, 1984). For example, an assimilator may possess strengths in reflective observation and abstract conceptualization. A converger would have more mental strengths in abstract conceptualization and active experimentation.

**Theory and models of brain-based learning**

In this section, we review the triune brain theory to understand the basic brain functions and how the brain functions for learning. This section focuses on the theoretical summary and learning models related to brain functions.

The *theory of the triune brain*. Based on the evolution of the human brain, MacLean (1990) developed the triune brain theory focusing on the three basic brain areas: the brain stem, limbic system and neocortex. Known as the reptilian brain, the brain stem controls the

<table>
<thead>
<tr>
<th>Functional areas of the brain</th>
<th>Primary functions</th>
<th>Learning domain</th>
<th>Kolb’s learning cycle</th>
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<tbody>
<tr>
<td>Frontal lobe</td>
<td>Thinking</td>
<td>Cognitive learning</td>
<td>Abstract conceptualization</td>
</tr>
<tr>
<td>Parietal lobe</td>
<td>Doing</td>
<td>Physical learning</td>
<td>Active experimentation</td>
</tr>
<tr>
<td>Occipital lobe</td>
<td>Watching</td>
<td>Visual learning</td>
<td>Reflective observation</td>
</tr>
<tr>
<td>Temporal lobe</td>
<td>Feeling</td>
<td>Affective learning</td>
<td>Concrete experience</td>
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</table>

Figure 4. Experiential learning model proposed by Kolb (1984)
basic survival functions such as breathing, sleeping, eating, heart rate, body mobility and balance by continuously monitoring and reacting to internal and external environments (Taylor and Marienau, 2016). In short, the brain stem is responsible for regulation and survival. The main parts of the brain stem are the hypothalamus (for temperature, appetite, hormones), thalamus (for senses except smell), pineal gland (for the body clock), midbrain (for reflexes), pons (for movement), medulla (for respiration and heart rate) and cerebellum (for balance) (Collins, 2016). The limbic system, called the mammal brain, provides basic functions for memory, learning, emotions and behavior (Taylor and Marienau, 2016). It helps enable emotional and feeling responses and influences value judgments and behavior (Henley, 2016). The functions of the limbic system are related to group and social connections (Taylor and Marienau, 2016). The significant areas of the limbic system include the hippocampus (for memories), amygdala (for emotion), corpus callosum (for information exchange between the left and right cerebral cortex) and olfactory bulb (for smell) (Collins, 2016). The neocortex (or cerebral cortex) is related to higher-order thinking, such as higher-level processing of information, communication, reasoning, analysis, imagination and logical and complex thinking (Taylor and Marienau, 2016). The neocortex accounts for 80-90 per cent of the whole brain weight and has functions that make humans unique (Henley, 2016).

Brain-based learning models. Brain-based learning emphasizes a comprehensive design and implementation of learning by combining cognitive, affective and psychomotor aspects and applying interactive relationships among the three aspects (Lim, 2016). To better understand the brain functions that facilitate and support learning, brain-based learning models provide guidelines for learning and pursue systemic and scientific analysis and application of learning based on neuroscience research (Gülpinar, 2005).

Multiple scholars have suggested brain-based learning models and principles for different contexts (Caine et al., 2005; Gülpinar, 2005; Hardiman, 2012; Lim, 2005; McCullough, 2014; Meier, 2000). For instance, Caine et al. (2005) introduced 12 principles of brain-based learning, based on three fundamental components related to learning environments including relaxed alertness (establishing an emotional and social environment for active participation), orchestrated immersion into a multifaceted learning context (providing ample chances and time for meaningful connections) and active processing of learning experiences (allowing optimal opportunities to solidify learning).

The 12 principles in the models include the following:

1. learning improves when the physiology of learning is satisfied;
2. learning is about attentive process through focused and peripheral perception;
3. learning involves both conscious and unconscious cognition;
4. learning is developmental;
5. the partial and whole brain simultaneously processes learning;
6. the brain is socially oriented;
7. the brain is uniquely organized;
8. learning is the process of finding meaning;
9. learning involves patterning processes;
10. emotions play a critical role in patterning;
11. learning utilizes two methods of memory system (rote learning and spatial/contextual/dynamic memory); and
12. learning can be boosted by engaging in challenging tasks and can be repressed by helplessness and fatigue.
Lim (2005) suggested another brain-based learning model based on cognitive, affective and psychomotor aspects. Brain development stages involve several systems including the limbic system (affective aspects) to the occipital lobe, temporal lobe and parietal lobe (psychomotor aspects) to prefrontal lobes (cognitive aspects). Thus, Lim’s (2005) brain-based learning model started from interesting (affective) to doing (psychomotor) to understanding (cognitive). This brain-based learning model identifies the cyclical relationships and interactive networks among the three aspects. It also emphasizes an evaluation of the learning processes and results, covering all three aspects of learning, and provides content-specific learning activities (Choi, 2010; Lim, 2005).

Hagen and Park (2016) developed a model of an adaptive cognitive neuroscience–adult learning structure based on andragogy principles. The four principles of andragogy include:

1. self-directed learning;
2. experience-based learning;
3. adults’ readiness in learning; and
4. application-focused learning (Knowles, 1980).

Hagen and Park (2016) suggested that these principles become a foundation for understanding how these learning processes occur in the brain. For example, adults’ prior experience is related to the prefrontal cortex of the brain, which leads to cognitive processes such as self-awareness, retrieval and recall. To utilize prior experience in a learning process, problem-based learning and experiential learning approaches can be useful as educational techniques to amplify encoding, retention and recall, which facilitates the formation of long-term memory. Hagen and Park’s (2016) model also provides useful guidelines to understand the neuroscience of cognitive learning through the lens of adult learning.

Several researchers have explained that accelerated learning is also closely related to brain-based learning because accelerated learning has been used as a useful teaching–learning method in practice by addressing cognitive neuroscience and cognitive neuropsychology (Boyd, 2004; Choi, 2015; Diamond, 2009). For instance, Meier (2000) developed a foundational model of brain-based learning emphasizing preparation, presentation, practice, and performance for HRD in companies and public organizations. From instructional design and implementation perspectives, Hardiman (2012) developed the brain-targeted model with five stages:

1. securing the climate for emotional learning;
2. establishing the learning climate for physical movement;
3. composing active experiences for learning;
4. maintaining the application of learning; and
5. evaluating learning.

**Neuroscientism: a brain-based learning theory**

Among the learning theories, traditional approaches have heavily focused on three primary theorems: behaviorism, cognitivism and constructivism. Behaviorism emphasizes conditioning as a universal learning process: classic conditioning and behavioral conditioning (Skinner, 1938). Behaviorist orientation has been criticized as being too concerned with single learning events and actions and too dependent on observable behavior to explain learning (Grippin and Peters, 1984). These cognitive theorists interpret learning as the process of acquiring or restructuring the cognitive memory through the
staged process utilizing schema, sensory register, information processing, short-term memory and long-term memory. Constructivists assume that learning is a complex process involving individuals’ past experiences, mental values and assumptions in interpreting objects and events (Jonassen, 1991). These three theories of learning have contributed to our substantial understanding of how people think and learn and influenced more advanced and diverse modern learning theories developed afterward. However, the relatively new notion of neuroscience-based learning is critical because learning is all about how the human brain functions. In addition, this view provides a good evaluative lens to judge which learning theories are valid in terms of neuroscience. Therefore, we propose that there must be a fourth learning theorem called neuroscientism. Simply put, neuroscientism is a brain-based learning theory incorporating various neuroscientific principles for learning and teaching. Neuroscientism has rarely been studied and researched, so it is not a mature theory but in the infant stage.

Neuroscientism is not a completely new theory of learning, but it is a more holistic approach to applying neuroscientific findings for learning and teaching. Neuroscientism also supports and strengthens existing theories of learning by proving neural experimental findings related to each theory. This research attempts to reveal what constitutes neuroscientism based on brain structure, brain mechanisms, cognition and brain-based learning models and to provide field examples adopting neuroscientific learning principles. In the following section, we present an in-depth analysis of the critical domains of neuroscientism including emotion, motivation, sense, attention and reflection for learning.

**Emotion and learning.** In discussing the core component of neuroscientism, emotion is one of the most critical aspects of brain-based learning. Although traditional approaches of learning have mostly focused on the cognitive and behavioral learning domains, the affective aspect of learning has recently caught the attention of learning scientists as industries have encountered various acute societal changes (Caine and Caine, 1994). For example, workplace burnout (emotional drain) has become a serious issue in the modern workplace (Weber and Jaekel-Reinhard, 2000). Considerable research has reported on burnout-impaired individuals’ cognitive functions, such as working memory, problem-solving skills and creativity (Golonka et al., 2017; Marin et al., 2011; Schaufeli and Salanova, 2007). Another affective issue in the labor force is that many employees have severely suffered from excessive emotional labor (Ashforth and Humphrey, 1993). As a result, a burnout syndrome and emotional labor have significantly impaired workplace employees’ mental capabilities and physical well-being.

According to several neuroscience studies, emotion is a very sensitive and influential moderator of memory-related processes such as cognition, attention, creativity and learning (Caine and Caine, 1994; Jane, 2001). The parts of the brain related to processing emotional memory include the thalamus, medial prefrontal cortex, amygdala, cingulate cortex and hypothalamus (Jung, 2011). Among these, the amygdala is the most important part of the brain controlling emotions because emotional memory is one of the most resource-consuming memories in the brain. When an individual is emotionally charged, the amygdala is heavily occupied with the task of processing emotional memories, leaving less resources to perform other functions such as cognitive memory processing, paying attention and encoding and retrieving of memories. (Kim, 2003; Kompus et al., 2009; LeDoux, 1996). Positive emotional memories activate the frontal cortex and anterior cingulate cortex in the brain (Caine and Caine, 1994; Wolfe and Brandt, 1998). A learning environment supporting positive emotions also facilitates verbal memories, decision-making and flexible and creative thinking.
Considering many important findings about the effects of emotion on learning, it is meaningful to pose an integrative view for learning from both cognitive and affective perspectives. That is, for effective learning to occur, it is critical to assess a learner's emotional state to establish a positive learning environment to promote positive emotions for learning. For example, Sprenger (2002) suggests that role-playing, mind reading, activities to form rapport among learners and physical movement are good learning activities for this purpose. Lim (2016) also recommends diverse learning activities that facilitate a learning environment with positive emotions including intentional smiling practice, writing emotional notes, writing worry notes, checking self-emotions before learning and mind control techniques (e.g. imagining of best/worst case scenario, mind mirroring, avoidance of negative feelings and emotional switch exercise). Recent neuroscience studies also suggest that reflective mental exercises, mediation and zen-type mind control techniques significantly increase attention, active processing of the working memory and the executive functions of the frontal cortex (Doraiswamy and Xiong, 2009; Posner and Rothbart, 2005).

Motivation and learning. Motivation is another critical component of neuroscientism and brain-based learning (Merriam et al., 2007). Learning can occur regardless of the level of motivation, but adults in workplace learning contexts learn more effectively when they are highly motivated (Knowles et al., 2005). Therefore, it is important to know what prepares the brain to learn and what promotes motivation for learning. In this study, we present four promotors of motivation for learning based on brain-based research findings.

Curiosity. According to Kang et al. (2009), curiosity may activate the caudate, the part of the brain associated with anticipated reward. When people are curious, they have a higher level of uncertainty but keep the level of uncertainty lower when searching for an answer or solution. Dopamine is released during this process, so people feel rewarded. Several learning strategies could be implemented to help learners increase their curiosity. First, people learn better when they guess. Yan et al. (2014) found that people learn better when they need to guess between two links or the answer to a question such as “What is the capital of South Korea?” Gruber et al. (2014) also identified that curiosity enhances people’s ability to learn and memorize new information in their experiments.

Using a questionnaire to motivate learners to explore a topic more is another strategy to enhance their level of curiosity via the dopaminergic circuit (Collins, 2016). Learning facilitators can particularly hide why, how or what while they describe content. For example, if a facilitator makes a surprising statement like “a company that puts priority on its customers will fail,” learners may be curious about the reasons behind such a statement. If a facilitator in an entrepreneurship training course says that he/she makes $10,000 a week while working only four days, learners may be curious about how that is possible. This type of curiosity promotes the brain activity level for learning.

Alertness. According to Wang et al. (2016), when a brain is on high alert (e.g. fear, physical pain), the person is prepared to fight and adapt to conflict. Therefore, providing an environment that generates a high level of alertness might promote short-term intensive learning. However, a fearful or stressful environment hampers logical thinking and information processing in the frontal cortex (Collins, 2016). Therefore, it is important for learners to be relaxed and reduce fear or mitigate a negative environment. In addition, when people are socially isolated, their brains feel it as physical pain. Because social relationships are critical for learning (Merriam et al., 2007; Smith, 1982), adult learners need to feel socially connected. This is why group-based learning activities either online or in class are good practices to facilitate a social learning environment.
Some of the strategies to help people feel comfortable, reduce stress and/or be more socially connected are giving learners an opportunity to introduce themselves to others and to satisfy their basic needs (e.g. refreshments and classroom temperature). Therefore, it is important to make the initial environment as welcoming as possible and to regularly pay attention to the environment. It is also critical not to criticize, argue or put people on the spot.

**Persistence.** One of the most difficult but critical aspects of motivation is persistence (Collins, 2016). Dopamine plays a critical role in motivation because it is associated with a reward, and it encourages people to achieve a goal. While motivation for learning could be divided into intrinsic and extrinsic motivation, intrinsic motivation could enhance persistence because it provides a reason that the learning is necessary for the learners (Pink, 2011). Therefore, instead of just focusing on the reward learners get when the learning is complete, it is critical for them to learn for the sake of learning or for their continuous personal development. Learners also sustain persistence in learning (intrinsically motivated) when they get a praise based on their learning performance (behavior-focused rewards), not based on how successful they are during the learning process (Cameron and Pierce, 2002).

**Playfulness.** Exploration and playfulness enhance creativity and help people become more open to new ideas (Bresciani Ludvik, 2016; Swart et al., 2015). One way to adopt this strategy in a learning environment is to promote feelings of relaxation by introducing a nature scene and/or sounds (Collins, 2016). Taking time out, a short nap or relaxation exercises could be other practices. In particular, Debnarot et al. (2011) found that daytime naps enhance motor imagery learning. Physical movement while learning also allows learners to be active in the learning process and increases the blood flow to the brain.

**Sensory learning.** The third component of neuroscientism is sensory learning. Human beings take in information through their senses. Brains are designed to function with rich sensory input, which is generally how brains learn. In addition, people learn better and memorize what they learn for the long term when they use various senses multiple times (Collins, 2016). Therefore, it is critical to adopt multisensory stimuli in learning design.

**Sight (visual learning).** Vision is usually the strongest sense. According to Schmeck et al. (2014), learners can improve their learning and absorb information when they draw something. Prangsma et al. (2009) identified that there may not be a significantly relationship between learning achievement and the use of diagrams, but they suggested that the use of graphics and visual aids makes it easier to grasp the learning content. In addition, learning improves when learners use visuals or pictures with text. Colors are also significant in learning because they influence how people pay attention, and higher attention enhances learning ability. For example, wearing red can help a facilitator feel more confident because the color red increases testosterone levels, which creates a higher level of energy (Farrelly et al., 2013).

**Sound (auditory learning).** Much less research about auditory learning has been done compared with visual learning (Collins, 2016). One of the strategies for using sound in learning is to give learners an opportunity to read materials aloud (think-aloud technique). In addition, learners can memorize materials and retain it long term when they create a poem, song or rap about the content to be learned. Changing learners’ emotional states by using music with major and/or minor keys is another strategy because major and minor keys can sound happy or sad, respectively.

**Touch (kinesthetic learning).** If the learning content is a physical skill, practicing the task is critical to learn and perfect the skill. However, the brain functions better when learners move because the brain needs oxygen, which can be acquired by physical moving (Medina, 2008). Using hand activities in learning allows a higher level of brain functions, as it changes the neurochemistry of our brain and triggers various parts of the brain (Wall, 2018). The
physical movement with hands also enhances cognitive skills. For example, a learning facilitator can develop physical mind maps and lay them out on the floor. Building models of concepts and asking people to walk around them is another strategy for learners to memorize the information, or simply give learners an opportunity to walk during a break.

Attention and learning. The olfactory cortex is near the front of the brain. Unlike other senses, olfactory perceptions go directly to the limbic system. Therefore, this fast route to the emotional center gives smell the power to elicit strong memories. Smell not only elicits direct emotional responses from learners but also affects their bodily functions such as blood pressure and heart rate. For example, when learners smell preferred odors, they feel good, which impacts skin conductivity, heart rate and eye-blink rates (Collins, 2016). This better emotional mood tends to make learners more creative and responsive.

Attention and learning. Attention is another critical domain of neuroscientism. Without sufficient attention, learners may not be able to focus and memorize what they learn. To illustrate, when the phone rings, everyone in the room pays attention to the phone. The external stimulus releases a burst of adrenaline that travels around the body and puts it on alert. However, when there is excessive arousal, performance decreases according to the Yerkes–Dodson Law (Yerkes and Dodson, 1908). Therefore, it is important to identify and facilitate an optimal level of arousal for attention. In addition, learners pay attention when there is self-reference. For example, when a facilitator uses learners’ names regularly, learners pay attention to what the facilitator is saying. Likewise, it is important to ask learners to reflect on what they are learning and to use the learners’ experiences (e.g. businesses, organizations, situations or cases) to enhance their learning (Knowles et al., 2005).

With a higher level of information processing, people pay attention better. According to Potter and Callison (2000), when people have higher auditory complexity, they are more alert, and their physiological levels of arousal also increase. However, when too much multitasking is needed to process information, it may significantly lower the attention level (Rock, 2008).

Reflective learning. Reflection is the fifth domain of neuroscientism. To create long-term memory, it is critical to review and reflect on what is being learned (Merriam et al., 2007; Rudy, 2014). Reviewing and reflecting on what is being learned builds and strengthens the neural pathways to store and retrieve information quickly and efficiently. Collins (2016) described an interesting analogy related to learning: building new neural networks is like building new relationships with people. In the beginning, two neurons have never met each other, but once they meet several times, they know each other much better. In reality, neurons are linked across the gap between synapses, and neurotransmitters are exchanged to send and receive electrical signals (Collins, 2016). The signals are initially weak and slow. However, as neurons repeatedly exchange signals, networks develop, the myelin sheath like a cable for networks becomes thicker and finally the links become faster and more efficient.

One of the learning strategies to build the myelin sheath is spaced repetition. Rather than cramming information into a short period, it would be more effective to space learning over a longer period. In addition, reviewing what has been learned 24h later — one week, one month, two months, three months and finally at six months — can lead to lasting long-term memory and learning. It is also important to build a learning culture of reviewing. To do so, a learning designer needs to schedule review activities as a part of the learning process. Table V summarizes the five domains of neuroscientism.
Cases for brain-based learning in the workplace

Neuroscience has helped us understand how people think and behave, and based on neuroscience findings, researchers have suggested that self-awareness, self-reflection and meditation are beneficial. To illustrate how workplace organizations apply brain-based learning principles in employee training, we provide several case examples in the USA and Asian countries.

Building the brain-friendly workplace. According to neuroscientists, developing the brain and behaviors can be effectively shaped by environmental exposure (Tost et al., 2015). Thus, many global leading companies have heavily invested in designing a nature-friendly office environment. Uniqlo, a major global apparel manufacturer and Japan’s largest apparel retail chain, renovated their headquarters into an open-plan office to facilitate communication between employees and promote teamwork (Flamer, 2017). Amazon, the second most admired company in the world in 2019, built their new headquarters as a functional office space with more than 40,000 plants inside. The reason for designing this unprecedented and innovative forest-looking office was the belief that when people are surrounded by plants or nature, it promotes thinking and working so employees can function better (McGregor, 2018). Google, another most admired company, has climbing walls and rooms for a variety of computer games and fun activities in their headquarters, so employees can enjoy these extra-curricular activities during office hours. These activities are believed to enhance employees’ creativity, the most important employee competency in their business. Google also built a treehouse workplace to provide a nature-friendly working environment (Loubier, 2017).

In South Korea, most training facilities for large conglomerates are located in rural areas where employees and trainees can be exposed to nature. When learners see nature scenes and hear nature sounds, they feel connected to nature and become energetic, creative, insightful and productive; as a result, they experience enhanced learning (Bringslimark et al., 2009; Nisbet and Zelenski, 2011; Passmore and Howell, 2014). When people are exposed to nature, their brains are stimulated while still feeling relaxed. This exposure gives the brain a chance to rest and promote cognitive processing and neural function. Interestingly, one of the companies located its training facility in the middle of the capital city, but employees were still exposed to gardens and other nature environments inside the facility in an attempt to bring about a similar effect as a rural training facility.

Using brain waves for workplace learning. Some companies have developed training programs based on brain waves. One notable example is Company H, a South Korean car parts company that manufactures and distributes its products in various continents. It currently has more than 25,000 employees. In 2011, Company H launched a neurofeedback program for 1,300 employees in one of its production divisions. This organization development initiative was meant to understand employees, communicate with them actively and transform their work lives positively through electrocorticography (measuring brain waves). In the pilot test, Company H selected several employees from each factory in South Korea and measured their brain waves before and after the program. This was the first training program for Company H using neuroscience.

Table V. Five domains of neuroscientism (brain-based learning theory)

<table>
<thead>
<tr>
<th>Emotion</th>
<th>Motivation</th>
<th>Sense</th>
<th>Attention</th>
<th>Reflection</th>
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<tbody>
<tr>
<td>Memory</td>
<td>Curiosity</td>
<td>Sight</td>
<td>Optimal level</td>
<td>Long-term memory</td>
</tr>
<tr>
<td>Learning environment</td>
<td>Alertness</td>
<td>Sound</td>
<td>Self-reference</td>
<td>Spaced repetition</td>
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<td>Persistence</td>
<td>Touch</td>
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<td>Playfulness</td>
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Company H has further developed the neurofeedback program, so employees can better understand themselves and others in their teams and departments. After measuring the employees’ brain waves using electrocorticography, Company H provides training programs for employees to enhance self-control and self-development based on each employee’s brain wave type. Using the electrocorticography machine, trainers can tell employees about their individual brain characteristics based on a report of alpha, delta, theta, and sensorimotor rhythm (SMR) waves. For example, engagement is shown from SMR waves, and creativity is from theta waves. After interpreting the waves, Company H identifies areas for improvement for each employee that will make them more productive and creative, depending on their jobs. Using these scientific data, Company H provides employees with a customized workplace learning program. Company H can also recognize where employees work best based on their brain waves. Company H plans to provide similar brain-based workplace learning programs in other parts of the organization in the near future.

Using neuroscience for creativity training. One of the largest conglomerates in South Korea, Company S, has provided various types of workplace learning programs to enhance employee performance including specialized brain-based programs to augment their employees’ workplace creativity. During the programs, learning program designers and facilitators monitored their trainees’ brain activity levels when they were being creative. In their brain-based coaching program, Company S also found that trainees could build more intuitive minds and bodies and perform more creatively when they practiced physical exercise and cognitive tasks. Through this program, employees were also able to understand themselves better and reduce stress quickly. More interestingly, after Company S recruited employees who were willing to participate in the brain-based creativity enhancement programs in the R&D center, the company measured the employees’ brain waves and provided coaching sessions based on the measured brain wave types. Due to the outstanding results from this program, the company plans to continue to expand the brain-based creativity enhancement programs throughout the entire organization.

Discussion
Implications for workplace learning and HRD
For about a decade, training applications based on neuroscience have emerged as a common theme at neuro-leadership-based associations and especially at a recent conference hosted by the Association of Talent Development (Stopper, 2016). However, it is important to validate many of the presented learning strategies applying neuroscientific principles before implementing them. For example, Rauscher et al.’s (1995) research findings on enhanced spatial task performance indicating that listening to Mozart makes people smarter became popular among college students. However, it was found later that this finding was over-interpreted, exposing the popular Mozart Effect myth. Without more scientific experimentation, this type of myth can mislead people. Therefore, any learning strategies based on neuroscientific findings should be empirically proven, and replication studies should be conducted in diverse contexts.

Understanding workplace learning based on neuroscience provides new perspectives and insights and may result in more effective learning designs and delivery. However, it is critical to comprehend how current workplace learning functions to make the most out of the new trials. There should be a balance between applying the most up-to-date neuroscientific findings to workplace learning and interpreting brain-based learning strategies from an authentic educational perspective. For example, any new attempt to use brain-based learning strategies should first be conducted on a small scale in a pilot test before full-scale implementation. When these two strategies are in balance, we can expect to devise more
proactive interventions for effective learning and HRD and achieve a desired level of performance outcomes within the current fast-paced, changing business environment. In addition, new Industry 4.0 technologies are expected to provide learners with enriched learning experiences. Smart learning technologies, such as virtual reality and augmented reality, have recently been applied to corporate learning. However, to make full use of smart learning technologies, research findings on the principles of neuroscience-based learning should be applied when deploying these technologies.

Several scholars have discussed how findings from neuroscience can be applied in workplace learning and organizations (Lagrosen and Travis, 2016; Merzenich, 2017; Zak, 2018). Our study echoes these research findings by emphasizing the role of neuroscience in workplace learning. For instance, the notion of brain plasticity (the ability to change brain capability) can be applied to workplace training by utilizing various brain-based learning activities to enhance employees’ cognitive and affective functions of the brain. Training programs boosting brain functions will improve employees’ creativity and decision-making capabilities while doing daily activities through faster cognitive speed and higher accuracy. These improvements are expected to result in better work performance in organizations (Merzenich, 2017). By introducing diverse functions of the brain and specifying which brain functions are directly connected to employees’ cognitive and behavioral tasks, our study encourages scholars to further examine how to integrate brain-based research to foster learning within the dynamics of the workplace.

Recommendations for future research
This study’s literature review provided insights about the core components of neuroscience and learning, brain-based learning and training programs and a neuroscientific approach for learning including brain-based learning models and strategies. This literature review on the neuroscience of workplace learning primarily explored how the brain functions, in general, and identifies how it relates to learning. However, most of the studies on neuroscience and learning have heavily focused on empirical results in academic educational settings. Only a handful of empirical studies have focused on workplace learning. We recommend more empirical studies examining the hypotheses of brain-based learning from a workplace learning perspective. The current study reduces the research gap and can be a cornerstone to link neuroscience and workplace learning. By reviewing the related literature and connecting neuroscience and workplace learning, this study has set the initial stage to link the two fields and verify what has already been identified.

As a foundational effort to expand the neuroscience-based learning research, it is necessary to clearly define terms, major concepts and typologies related to these two fields. Some terms and concepts used in both fields could have different meanings and vary in terms of when and how they are used. For example, some researchers have used triune brain theory as the basis for explaining the major functions of the brain to illustrate how this theory is related to learning (MacLean, 1990; Taylor and Marienau, 2016). Other researchers have used a more detailed specification of the brain structure to describe the cognitive and psychomotor functions of different brain parts for learning (Collins, 2016; Lim, 2016). As the way we define and describe terms and concepts could affect the methodologies and interventions used for brain-based learning in the workplace, these terms and concepts should be clarified to initiate new research focusing on neuroscience and workplace learning.

Neuroscience describes how the brain functions. A few learning applications have already been incorporated based on neuroscience. For example, Hagen and Park (2016) explored how the literature on cognitive neuroscience has led to andragogically informed
instructional practices. However, it would be interesting to further explore how neuroscience can be integrated into traditional theories/principles of workplace learning and why these theories work from a neuroscientific perspective. In addition, future research could be expanded to examine how neuroscience promotes performance, prosocial behavior and trust as part of learning outcomes in organizations. More importantly, it would be fascinating to see how findings from neuroscience can be applied to informal learning in the workplace.

Although various industry-level training interventions based on neuroscience have been implemented, an important research area to investigate would be the effectiveness of such attempts with an educational lens and performance perspective. Simply identifying findings from these training initiatives based on neuroscience is context-bound. A deeper and/or replicated examination would provide a more fundamental understanding about whether certain brain-based learning principles and strategies can be generalized. Research efforts could also move forward to assess under which circumstances and instructional contexts they can be effective and successful.

Conclusion
In reflecting on the critical role of neuroscience for various aspects of learning and employee development in the workplace, it is imperative to perform a more in-depth review of neuroscientific findings that can be optimally applied to diverse dimensions of HRD activities. To satisfy this need, we conducted a thorough review of the literature on neuroscience and reflected on various meaningful ideas for research and practice. Although we believe this study is just one scholarly attempt to determine how to connect neuroscience and HRD, we hope this becomes a stepping-stone to develop and create more solid theory-building and organizational practices.

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