Title

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Editorial Special Topic: Neuroscience, Learning, and Educational Practice—Challenges, Promises, and Applications

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Abstract

There is growing interest in the contributions of neuroscience to educational practice; however, to date, neuroscience seems to have had little impact on education. Nonetheless, neuroscience has potential value for education on several fronts, as illustrated by the articles in this Special Topic. These articles provide excellent examples for how neuroscientific approaches can complement behavioral work, and they demonstrate how understanding the neural level can help researchers develop richer models of learning and development. These articles further show that, ideally, research efforts in neuroscience and education should be reciprocal. Specifically, education should encourage psychology and neuroscience to develop learning theories that are relevant in the real world and further improve our understanding of how specific instructional practices affect learning and achievement; in turn, psychology and neuroscience can provide insights into underlying neural and cognitive mechanisms of learning, with the overall goal to maximize human potential and learning for all.

Keywords

cognitive processes/development; experimental research; mathematics education; motivation; neuroscience; reading; special education

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There is growing interest in the contributions of neuroscience to educational practice, as evidenced by an increasing number of conferences dedicated to this topic, as well as societies, journals, and graduate programs (Hook & Farah, 2013). Nonetheless, to date, neuroscience seems to have had little impact on education and education research (Mayer, 2017), and many scientists have argued that the implementation of neuroscientific research into educational practice is still “a bridge too far” (e.g., Bruer, 1997; Bowers, 2016; but see Howard-Jones et al., 2016). Nonetheless, neuroscience has potential value for education on several fronts. First, neuroscience methods have the potential to help develop deeper mechanistic models of learning and cognitive growth. Specifically, neuroscience can provide constraints on behavioral models as well as converging evidence for psychology-level theories (Howard-Jones et al., 2016). As such, neuroscience might provide insight into whether a particular intervention might be effective. Second, neuroscience methods can advance our understanding of the underlying basis of deficits such as attention-deficit/ hyperactivity disorder, dyslexia, and dyscalculia (Bowers, 2016). Third, neuroscience might help us to assess whether an intervention or instructional strategy has an intended impact. Finally, neuroscience methods may be useful for the early identification of potential learning difficulties (e.g., auditory processing problems that might precede behavioral evidence). However, it has been difficult to evaluate the degree to which neuroscience evidence per se can provide the key for understanding learning and development; specifically, the question is about the value of the neuroscience added above and beyond what can be provided by behavioral work.

The articles in this Special Topic provide excellent examples for (a) how neuroscientific approaches can add to and complement behavioral work and (b) how neuroscientific findings can inform educational practice and/or policy. Furthermore, the work presented here incorporates a range of approaches—including cognitive, developmental, and neuroscientific methodologies—with the common goal to elucidate how neuroscience might inform our knowledge of how we learn and how it might ultimately inform educational practice. Overall, the Special Topic consists of five contributions by 19 authors: three are conceptual review articles, and two are primary research articles.

Al Dahhan, Kirby, and Munoz (2016; this Special Topic) focus on the development of reading skills, as well as the difficulties to acquire those skills. Reading ability and reading deficits have been studied in different disciplines—most prominently, in neuroscience, cognitive psychology, and education. However, the efforts have often been disjointed, and the authors argue that a cross-disciplinary integration of different disciplinary perspectives might provide a more complete and potentially transformative understanding of how typical and atypical reading emerges across development, which is critical for the development of effective interventions that could be implemented in educational settings. By using naming speed tasks as proxies for general processes involved in reading, they aim to provide a general framework that could bridge the gap among neuroscience, cognitive psychology, and education. They illustrate how neuroscience and cognitive psychology could play an important role in the early assessment of risk factors by integrating neuroimaging techniques, eye tracking, and behavioral assessments, as well as in revealing the potential mechanisms by which educational remediation approaches might be successful. Their article then serves to demonstrate how converging evidence from those different disciplines has contributed to models of reading development and difficulties.

Relatedly, *Kim and Cameron* (2016; this Special Topic) take a developmental neuroscience approach to illustrate the relationship between domain-general cognitive processes—specifically, executive functions and visuospatial skills—and mathematics learning. They describe how those domain-general processes differentially contribute to and support the learning of mathematical skills in typically developing and atypical populations, with the overall goal to demonstrate how neuroscience could be used to inform educational practice. They argue that the study of atypical development can be especially helpful to get a better understanding of mathematics development and its underlying cognitive and brain mechanisms. To illustrate their point, they focus on two neurodevelopmental disorders—namely, autism spectrum disorder and Williams syndrome. They show that individuals with autism spectrum disorder and Williams syndrome display distinct cognitive profiles, differentially affecting domain-general processes, and how they contribute to deficits in mathematical learning. As such, the focus on those disorders can reveal potential difficulties and/or developmental limitations in the acquisition of mathematical skills, which can in turn facilitate the development of interventions or strategies to help children with specific mathematical learning difficulties.

Libertus et al. (2017; this Special Topic) take a different approach to understand mathematical learning; they use evidence of shared neural networks to guide their interventions. They focus on interventions to boost both domain-general and domain-specific skills—mathematical skills in particular. Specifically, they investigate whether and how action video games that are thought to improve attentional brain networks might also affect mathematical skills, given that they are assumed to rely on similar frontoparietal brain regions. They asked a sample of college-aged participants to engage in extensive video game training, testing them extensively on a battery of outcome measures after 25 and 40 hours of training. Half the participants trained on an action video game, and the other half trained on a nonaction video game, which served as an active control. Unlike the authors' prediction, the action video game training did not result in improvements in basic attentional and numerical skills as compared with the active control training; however, the improvements in attentional control during the first part of the intervention were correlated with the overall improvements in basic number processing, indicating that those two processes are indeed related. The authors suggest that this pattern could be taken as further evidence that interventions that successfully improve attentional control might have the potential to improve other cognitive functions that rely on those functions. Interestingly, the action video game training group did demonstrate some generalizing effects in standardized mathematics assessments requiring complex mathematical computations, which suggests that—despite the widespread public concerns—playing action video games might not be detrimental for performance in school-related tasks; quite the contrary, it might actually support the development of complex mathematical skills.

Mangels, Rodriguez, Ochakovskaya, and Guerra-Carrillo (2017; this Special Topic) use neuroscience methods as a tool for assessing the impact of a small-scale intervention. They focus on achievement goals that are thought to influence individuals' attention to and interpretation of achievement-relevant information, and they rely on behavioral and electrophysiological methods to understand the neural mechanisms and consequences of differential achievement goals and how they relate to learning. Specifically, they investigate how task instructions that emphasize the importance of mastery or performance goals to complete a challenging test might influence the neural response to negative feedback, as well as participants' task engagement and their ability to use this learning feedback to improve their performance in a delayed surprise test. Overall, the results show that task goal framing did not affect the neural response to feedback processing; however, it differentially predicted successful encoding of the learning feedback as determined in the surprise feedback test. Mastery goal framing was associated with distinct frontotemporal activity reflecting semantic and/or conceptual processing, whereas performance goal framing was related to parieto-occipital activity, reflecting more superficial perceptual processing; however, those differential effects were not reflected in the behavioral outcomes. Importantly, the magnitude of those neural signatures was influenced by whether the task goal framing was consistent with the participants' personal goals, which has implications for educational practice given that more and more educators are relying on mastery-oriented approaches in their classrooms. That is, even though the emphasis on mastery goals is typically correlated with better learning outcomes, a mismatch with individuals' personal goals might actually negatively affect learning processes.

Finally, *Heissel, Levy, and Adam* (2017; this Special Topic) review the literature on stress, illustrating how stress exposure results in changes in multiple biological systems—ranging from the activity of the hypothalamic-pituitary-adrenal axis and its hormonal product, cortisol, to the pattern of the circadian rhythm and sleep. Importantly, stress exposure, hypothalamic-pituitary-adrenal activity, and sleep interact, and they can all significantly affect cognitive functioning and test performance. Furthermore, stress exposure and the resulting biological changes are differentially affected as a function of socioeconomic status and race/ethnicity, which has important educational implications in that those factors might contribute to the persistent racial-ethnic and socioeconomic achievement gap. In particular, stress exposure—which is more prevalent in low-income and minority populations—has detrimental effects on learning as well as the way that students respond to stressful situations, such as high-stakes testing. The authors propose potential ways to address those issues. First, they recommend paying more attention to how stress exposure affects student learning, and they emphasize the development of strategies that focus on the reduction of (perceived) stress levels—for example, by using more holistic measures of student achievement and/or the implementation of mindfulness interventions. They also suggest strategies that focus on the improvement of sleep quantity and quality—all of which might be especially beneficial for low-income and under-represented minorities.

Overall, the five articles in this Special Topic describe potential avenues illustrating how neuroscience might inform psychological and educational research and practice. All articles demonstrate how understanding the neural level can help researchers develop richer models of reading development, mathematics learning, and the impact of stress on development. The article by Libertus and colleagues (2017) further illustrates the potential benefit for using knowledge about shared neural networks for guidance on developing interventions. In addition, the article by Mangels and colleagues uses neuroscience as a tool for understanding the impact of an intervention that may not be detectable (or understood) without the neural evidence. Each of these articles therefore uses neuroscience for a distinct purpose that provides added value above behavioral data.

These articles also show that, ideally, research efforts in neuroscience and education should not be unidirectional; rather, they should be reciprocal (see also Mayer, 2017). Specifically, education should encourage psychology and neuroscience to develop learning theories that are relevant in the real world and further improve our understanding of how specific instructional practices affect learning and achievement; in turn, psychology and neuroscience can provide insights into underlying neural and cognitive mechanisms of learning, with the overall goal to maximize human potential and learning for all.

Finally, we note that it is important for the research community to be cognizant of the potential seductive "allure" of neuroscience (Rhodes, Rodriguez, & Shah, 2014; Weisberg, Keil, Goodstein, Rawson, & Gray, 2007). This seductive allure can be used for good: to bolster the strength of a well-supported educational policy recommendation, for example. Or, it may be inadvertently used to imply that a recommendation is better supported because it relies on “brain based” research.

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Biographies

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