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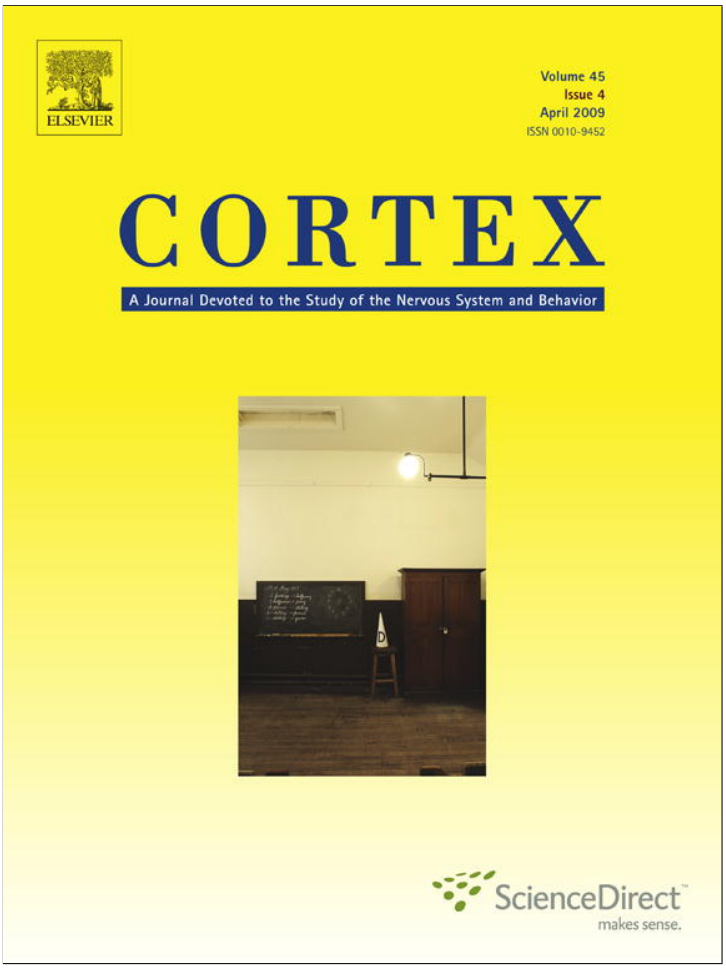
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Discussion forum

Three problems in the marriage of neuroscience and education

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Whether neuroscience can be informative to educational theory and practice is not debatable—it has been. For example, behavioral data were not decisive in determining whether dyslexia was primarily a visual perceptual disorder, or whether phonology was the more fundamental problem (for a review, see McCardle et al., 2001). Brain imaging data (e.g., Rumsey et al., 1992) showed reduced activation in left temporoparietal cortex, a region known from other studies to support phonology, thus strongly supporting the phonological theory.

The question is just how enthused and optimistic should researchers, educators, and parents be? It is wise to remember that there have been at least two other brief pulses of excitement over a possible marriage between these two fields—one in the mid 1960s (e.g., Gaddes, 1968) and the other in the early 1990s (e.g., Vellutino et al., 1991). Will the recent reigniting of the romance lead to a long-term commitment, or will it be another passing infatuation? Here I highlight three problems in bringing neuroscientific data and theory to bear on educational practice.

Before I describe those three problems it will be useful to draw a distinction between natural and artificial sciences (Simon, 1996). Natural sciences, like neuroscience, are descriptive; the aim is to discover principles that describe neural structure and function and in so doing to bring order and comprehensibility to data. Artificial sciences are normative. Their aim is not the description of the natural world as it exists, but the creation of an artifact, designed to serve a specified goal, within a particular environment. Examples of artificial sciences include urban planning, economics, engineering, and education. The artifact to be created in education is a set of pedagogic strategies and materials. The goal is usually some version of "instilling skills and knowledge in children," although the goal changes over time and across cultures. The aim of the field as a whole is to create a version of the artifact that best fulfills the goal.

How are natural and artificial sciences related? Natural sciences can inform artificial sciences. For example, a civil engineer uses fundamentals of physics when designing a bridge, and an urban planner might use chemistry, meteorology, and physics in projecting the growth of an urban heat island. An educator designing a pedagogical strategy would be well-advised to use knowledge about how humans learn, attend, understand language, grow fatigued, resolve conflicting cognitive demands, regulate emotion, become motivated, behave in groups, respond to authority, and so on. It would seem that neuroscience would be well positioned to provide some of this information. Neuroscientific data on these and related subjects is growing exponentially. It is easy to see why some enthusiastic cupids are certain that neuroscience and education are made for one another. There are, however, three problems that significantly reduce the likely frequency and depth of the contributions that neuroscience can make to education.

First, artificial sciences are driven by goals, and the desiderata set by some goals are ones for which natural sciences are not informative. For example, one goal in the construction of a bridge will be to support a projected traffic stream, and physics will be useful in that calculation. But another goal may be to create a bridge that beautifies the landscape and the natural sciences remain silent on this matter.

Goals for children's education often include features to which the natural sciences will not contribute. For example, in mid 19th century United States, the goal for elementary schooling was primarily character development (Nasaw, 1979). Today, a frequently cited goal for preschoolers is development of aesthetic sense (Bredekamp, 1987). When the goals for schooling include problems that are outside of

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neuroscience's purview, it is clear that neuroscience will *never* provide a prescriptive solution. I call this the "goals problem."

The second problem is one of levels of analysis. The uppermost level employed by neuroscientists concerns the mapping of brain structure and activity to cognitive functions (e.g., memory, attention) or function interactions (e.g., the impact of emotion on learning). Neuroscientists study these cognitive functions in isolation for the sake of simplicity. They do not study the entire nervous system, working as a whole with all of the attendant interactions among components. For educators, the mind of a single child is the lowest level of analysis with any payoff. Higher levels include the classroom, school, neighborhood, and country. The information that education researchers most often try to import from neuroscience concerns a single cognitive process in isolation, but the interactions with other systems will be part of the educational context. For example, we know that repetition benefits memory, but a teacher cannot ask students to repeat work without considering the impact on motivation. Neuroscientists usually cannot characterize these interactions. I call this the "vertical problem."

Third, one must find a way to translate the contents of the two fields. Educational theory and data are purely behavioral. Neuroscientific theory and data take many forms, because the nervous system has many features: electrical, chemical, spatial, temporal, and so on. The data most often recruited for education are those that spatially map human cognitive processes and representations to the brain. How does one actually *apply* data about the localization of function to purely behavioral theories? For example, suppose one concludes that the intraparietal sulcus contributes to number sense in arithmetic. What's next? I call this the "horizontal problem." Elsewhere I have enumerated methods of solving the horizontal problem (Willingham and Lloyd, 2007) and indeed, there have been notable successes using these methods, for example, in identifying subtypes of dyslexia (Shaywitz et al., 2006). Like other researchers (e.g., Bruer, 1997; Geake and Cooper, 2003) I have argued that neuroscientific data are primarily useful in their contribution to behavioral data when a rich body of data and theory exists at the behavioral level.

Any marriage will be more successful when each partner has realistic expectations of the other. Educators should expect that neuroscience (1) will not be prescriptive; (2) will remain silent on educational goals that are incompatible with neuroscientific analysis (e.g., aesthetic training), and will omit levels of analysis beyond the individual, and; (3) neuroscience will prove helpful on targeted questions at a more-fine grained level of analysis such as how people read, learn, and attend, but these data will only be useful in the context of well-developed behavioral theory.

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