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(Editors)

Neuroscience and Education

Added Value of Combining Brain Imaging and Behavioral Research

Zeitschrift für Psychologie
Founded in 1890
Volume 224 / Number 4 / 2016

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Editorial

Educational Neuroscience

A Field Between False Hopes and Realistic Expectations

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The tremendous progress in brain imaging techniques made in the past decades has become an ongoing chance but also a challenge for the behavioral sciences – first and foremost for psychology and the educational sciences. Highlighting the neural activities underlying cognitive, emotional, and behavioral processes has considerably contributed to a better understanding of the architecture and the functioning of the human brain. To what extent progress in neuroscience can account for a better understanding of human learning and thereby inform educational theories and practice has been under debate in the past two decades. Nonetheless, numerous fruitful collaborations between educational researchers and neuroscientists have emerged, which resulted in the development and growing salience of the interdisciplinary research field, Educational Neuroscience. The principal goal of this research field is to achieve a broader understanding of the neurocognitive mechanisms underlying successful learning and to develop effective interventions based on the accumulated evidence.

In 2004, the German Federal Ministry of Education and Research invited us to write a report on the limits and the potentials of bringing together educational research and neuroscience, bolstered by experts from psychology, pedagogy, and neuroscience (English version: Stern, Grabner, & Schumacher, 2006). We came up with an overview of the then state-of-the-art techniques, knowledge about the architecture of the human brain, and some perspectives worthwhile to be addressed from an interdisciplinary perspective. We also emphasized principal limitations of explaining human learning and behavior by referring to the neural level, which we also emphasized in other publications (Schumacher, 2007, Stern, 2005; Stern, Schumacher, & Grabner, 2014). It goes without question that for a better understanding of human learning in academic settings, constraints set by the architecture of the human brain have to be taken into consideration. To the best of our knowledge, the genetic codes that guide human brain development did not undergo significant changes in the past 40,000 years. Given that cultural symbol systems like script and numbers started to emerge only 5,000 years ago, it becomes pretty obvious that our brains have not been evolutionarily adapted to our today's academic and technical world. However, human's extraordinary learning capacity, which includes the ability to learn by instruction provided in institutional settings, nonetheless allows them to acquire academic competencies within few years that took mankind centennials to develop.

In our report from 2006 we emphasized that in order to better understand what makes human brains so unique, we have to study them during unique human activities, which is learning to use symbol systems as reasoning tools. This has been extensively done in the past decade, among many others also by one of the editors. The research of brain functioning during mathematical reasoning has shed light on the interaction between evolutionary ancient systems of numerical information processing and symbolic competencies that allowed the acquisition of mathematical competencies (Grabner & De Smedt, 2016; Grabner & Vogel, 2015; Grabner et al., 2010). Even more educational neuroscience research has been conducted on the questions of what brain functions enable most human beings to become literate after few years of instruction, and why this instruction does not work equally well for everybody. Consequently, the first of the review articles (Bédard, Laplante, & Mercier, 2016) of this topical issue focuses on dyslexia and discusses the added value of combining behavioral and neuroscientific data. This discussion is continued in two opinion papers (Landerl & Banfi, 2016; Schneider, 2016), in which examples of chances and limitations of educational neuroscience research on dyslexia are presented.

In the 2006 report, we also identified the neural correlates of processing errors and feedback as a worthwhile

DOI: 10.1027/2151-2604/a000258

research question. The review article from Dion and Restrepo (2016) is demonstrating that many other scientists have shared this view. This article is seconded by a spotlight on electrophysiological indices of error and feedback processing (Schillinger, 2016) and an opinion which emphasizes peculiarities of feedback processing in the developing brain (Hauser, 2016). In the original article by van der Ven, van Touw, van Hoogmoed, Janssen, and Leseman (2016), an electrophysiological index of semantic processing was used to investigate effects of reward prospect on learning. Their findings suggest that the beneficial effects of reward prospect are related to qualitative changes in cognitive processing strategies.

What is indispensable for academic instructional learning is a functioning working memory which is handling the pursuit and achievement of goals by controlling attention. Thanks to including brain imaging techniques psychology has made considerable progress in refining theories of working memory functions. One of the functions that is being increasingly recognized to play a pivotal role for instructional academic learning is inhibition. Efficient learning requires not only fading out all incoming stimuli distracting from the learning goal, but also the inhibition of inappropriate knowledge or reasoning. The role of inhibition in understanding concepts of mathematics that go beyond counting with natural numbers has been nicely demonstrated in the original paper from Stavy, Babai, and Kallai (2016) which is dealing with proportional reasoning. Having to take into account the relation between two quantities rather than the quantities themselves, for example understanding that 3/4 is larger than 4/8, requires to inhibit well-established knowledge about natural numbers, a view also emphasized in the opinion piece of Obersteiner (2016). Ahr, Borst, and Houdé (2016) argue in their original article that inhibitory control is a necessary feature of the learning brain. The acquisition of sophisticated cultural tools like script and mathematics symbol systems would require the functional recycling of brain areas, whose initial function was close to the new demand, and the inhibition of the initial function, a line of argumentation that is seconded in the opinion piece of Kiper (2016).

Finally, the present issue comprises three spotlight articles, which further illustrate the value of adding the neuroscientific level of analysis. Cockerham and Malaia (2016) discuss the need for an interdisciplinary perspective for a better understanding of autism spectrum disorder. Charland, Léger, Mercier, Skelling, and Lapierre (2016) introduce implicit measures of cognitive and emotional engagement to predict learning. And Çakır, Akkuş Çakır, Ayaz, and Lee (2016) present a pilot study on neural changes accompanying a game-based arithmetic training, which is reflected from a mathematics education perspective in another opinion piece by Verschaffel (2016).

In a nutshell, extending research on human learning by including neuroscientific techniques has markedly contributed to a better understanding of what makes the human brain unique and how neural constraints might impede benefitting from institutional learning environments. A central prerequisite for the success of educational neuroscience is the acknowledgment that different levels of data and multiple perspectives need to be integrated rather than isolated. This holds particularly true for neuroscientific data, which can only be interpreted when linking them to behavioral data and cognitive theories. This point is explicitly stated in many of the issue's articles. By this multimethodological approach new insights into human learning can be achieved, which, in turn, are relevant for educational research and practice. Therefore, the expectation that insights from neuroscience alone can provide direct hints of how learning environments should be designed is mistaken and unrealistic.

We thank all authors and reviewers for contributing to the quality of this topical issue and are looking forward to future fruitful research on better understanding of human learning that will bring together different levels of analysis and multiple perspectives.

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Published online February 8, 2017

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