Social cognition of children and young adults in context

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CHAPTER 2

Educational neuroscience: its position, aims and expectations

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ABSTRACT

An important issue in the discussion on educational neuroscience is the transfer of thought and findings between neuroscience and education. In addition to factual confusions in this transfer in the form of neuromyths, logical confusions, or neuro-misconceptions, can be identified. We consider these transfer difficulties in light of the way educational neuroscience is positioned in relation to the main fields involved: neuroscience, educational sciences and educational practice. A distinction between educational neuroscience as part of neuroscience, educational sciences and as an independent discipline will show that different types of questions are asked within these different positions. Distinguishing these positions will also shed light on the aim and possibilities to transfer knowledge and insights into educational practice and will elucidate the confusions in transfer. While educational neuroscience as part of educational sciences and as an independent discipline aims to directly connect to educational practice, be it in different ways, educational neuroscience as neurosciences does not have this goal or possibility.

INTRODUCTION

The transfer of thought, ideas and findings between neuroscience and education remains a core point in the discussion on educational neuroscience (Ansari et al., 2012; Geake, 2008; Howard-Jones, 2007; Pincham et al., 2014). Persisting difficulties in this transfer lead to questions about the feasibility and value of the field. Concerns have been and continue to be expressed on issues of methodology, communication and theoretical frameworks (for example Varma et al., 2008). We aim to bring clarity to the discussion by elucidating the conceptual positioning of educational neuroscience—how educational neuroscience, often referred to as an interdisciplinary or transdisciplinary field (Ansari et al., 2012; Beauchamp & Beauchamp, 2013), relates or aims to relate to the two main disciplines that are involved, i.e. neuroscience and educational sciences, and educational practice. We will make a distinction between educational neuroscience as part of neuroscience, as part of educational sciences and as an independent field and will show that different sorts of questions are addressed within these positions. It will become clear that these positions and their characteristic research questions and aims differ mainly in the extent to which they contain the element of (informing or relating to) educational practice.

The main part of the article consists of a description and discussion of these three positions, but first we will give a brief summary of the possible difficulties in the transfer between neuroscience and education. We describe the often discussed neuromyths (referring to concrete confusions of brain functioning such as a distinction between "left-brainers" and "right-brainers") to which we add less often identified transfer problems, namely "neuro-misconceptions" (abstract or theoretical confusions, for example an incorrect understanding of the relation between the brain and the mind).

CONFUSIONS IN TRANSFER

Neuromyths refer to popular but confused conceptions of various aspects of brain function (Alferink & Farmer-Dougan, 2010; Fischer et al., 2010; Geake, 2008; Purdy, 2008). They are the most often identified and described forms of transfer problems between neuroscience and education. Examples are distinctions between "left-brainers" and "right-brainers" or between visual, auditory and kinaesthetic learning styles (Geake, 2008; Purdy, 2008). These types of neuromyths have for example contributed to the idea of brain-based education in which children are being tested and consequently treated in relation to their dominant learning style.

Neuromyths, including their genesis, acceptance and persistence, have become an area of research itself (Geake, 2008). Responsibility or blame has been ascribed to neuroscience, to educational practice and to the communication between neuroscience and educational practice. On the one hand, educational practice has been described as a "soft target for neuroscience" (Howard-Jones, 2009, p. 550). Enthusiasm among teachers to understand learning at the biological level combined with a lack of expertise or basic knowledge in this area can contribute to incorrect generalisation and misinterpretation of neuroscientific insights (Goswami, 2006; Howard-Jones, 2009; Purdy, 2008). Taking a more critical stance towards the attitude and position of teachers, the easy acceptance of these myths could reflect a lack of (capability of) critical evaluation of complex scientific findings (Geake, 2008). On the other hand, responsibility has been placed on neuroscience that has not been successful in describing and communicating their findings effectively (Goswami, 2006). This includes being clear on the limits and implications of neuroscientific research methods such as fMRI (Alferink & Farmer-Dougan, 2010; Racine et al., 2005). Since both the description and interpretation of neuroscientific insights contribute to neuromyths, the transfer of neuroscientific findings out of the laboratory into the classroom can be identified as the place where these myths emerge (Geake, 2008; Howard-Jones, 2007).

We believe that a second type of transfer problems can be identified in addition to these concrete neuromyths. While neuromyths refer to confusion about relatively concrete, specific neuroscientific findings or insights, this second type of confusion concerns general theoretical ideas or frameworks of neuroscience. These confused or distorted theoretical ideas, or "neuro-misconceptions", have been far less extensively identified and described (though see Bennet & Hacker, 2003; Cromby, 2007; Davis, 2004). An important point of distinction between neuromyths and neuro-misconceptions is that neuro-misconceptions are not factually wrong but do not make sense logically (Bennet & Hacker, 2003). It is factually incorrect to distinguish between learners with either a dominant left or right brain, but as the example below will clarify it is logically incorrect to reduce a person to his or her brain as this confuses (the relation between) the brain and the mind (Bennet & Hacker, 2003).

Transfer problems have been attributed to differences between the explanatory frameworks of neuroscience and the educational field (Bakhurst, 2008; Davis, 2004; Schumacher, 2007). In describing the differences between the frameworks, it is suggested that the framework of neuroscience emphasises the understanding of behavior as the endpoint of causal events (see Cromby, 2007). This causality, which would eventually be explained using the laws of the natural sciences, is most often conceived of as flowing from brain to mind to behavior, rather than vice versa (Howard-Jones, 2008). The framework in educational thinking however emphasises the explanation of behavior in terms of reasons (Bakhurst, 2008). Individuals are considered reasonable and intentional agents, who behave both within and in interaction with a particular social, cultural and natural environment. Conflating these two frameworks leads to neuro-misconceptions. One example is referred to as brainism (Bakhurst, 2008) or neuro-essentialism (Racine et al., 2005). Statements such as "the brain thinks", "the brain decides" or "the brain is confused" reflect the incorrect understanding of the relation between the brain and the mind (Bakhurst, 2008; Bennet & Hacker, 2003). These statements refer to ascribing psychological attributes, normally ascribed to persons, to the brain (Bakhurst, 2008; Bennet and Hacker, 2003). The brain is used in the same way more global concepts such as persons, individuals or selves are used (Racine et al., 2005). Persons are thus reduced to merely brains; "neuro-essentialism represents a hasty reduction of identity to the brain" (Racine et al., 2005, p. 3).

This brief description serves the purpose of showing how in addition to neuromyths, neuro-misconceptions can be identified that can be considered more subtle and more difficult to deal with than neuromyths. Neuromyths can in part be seen as a consequence of neuro-misconceptions: neuro-misconceptions add to misinterpretations since they contribute to an overall confused or simplified framework of the working of the brain, in which light more concrete neuroscientific findings are being interpreted and further distorted into neuro-myths. A further, more detailed analysis of the misconception of brainism is beyond the scope of the current article (see Bennet & Hacker, 2003 for such an analysis). We will however conclude this section with an example of a relatively common neuro-misconception.

In the discussion of the value of educational neuroscience, it has been suggested that neuroscience is mostly or only relevant for the education of children with deficits or disorders; neuroscience can assist educators of children with serious difficulties by identifying and locating neurophysiological problems (Davis, 2004). For example, neuroimaging findings showing a clear difference in brain function or structure between learners with serious difficulties and typical learners could be helpful in identifying the origin of the difficulties of these learners. While we do not want to deny the relevance of insights of neuroscience in cases of disorder or dysfunction, the misconception of "brainism" can easily enter into this line of reasoning. First, it seems to suggest that in case of children with deficits or disorders, one can understand and explain their behavior from their brain functioning even if one acknowledges the mistake of brainism in the case of typical development. This seems to presume that it is possible to distinguish between different types of children in the overall perspective of understanding their behavior, which appears to be an unnatural and forced distinction. Second, although healthy functioning of the brain is a necessary condition for the typical functioning of a person (which everyone agrees on), it is not a sufficient condition nor does it mean that there is a simple causal relationship between a deficiency in the brain and behavior. The misconception of brainism appears if a deterministic interpretation is applied to cases of children with deficits or disorders, presuming that if we know that a child has a particular brain disorder, we thereby fully understand why she behaves in a particular manner.

POSITIONING OF EDUCATIONAL NEUROSCIENCE

In the first part of this article, we described the problem of transfer between neuroscience and education that becomes apparent in neuromyths and neuro-misconceptions. We will continue by considering this problem in light of the conceptual positioning of the field of educational neuroscience. It is often not explicitly discussed how educational neuroscience is positioned in relation to neuroscience, educational sciences and educational practice (but see Ansari et al., 2011; Beauchamp & Beauchamp, 2013; Pincham et al., 2014). We will show the importance of this positioning, that both determines and reflects the questions educational neuroscience asks and the approach taken in answering these questions. Moreover, the discussion of these different possibilities for the positioning of educational neuroscience will clarify how confusion on this positioning relates to the problems educational neuroscience continues to face sketched above.

Considering the positioning of the field

Educational neuroscience concerns two main disciplines, i.e. (cognitive) neuroscience and educational sciences, and educational practice. The conceptual positioning of educational neuroscience refers to the relations that exist between these three fields and the directions of these relations. This section will describe and discuss three main options: educational neuroscience as an integral part of neuroscience, as an integral part of educational sciences and as an independent field.

The importance of the distinction between these different options is indicated by Willingham's (2009) description of the distinction between natural and artificial sciences and the different aims of these types of sciences. This distinction is used by Willingham in discussing problems in the collaboration between neuroscience and education. As Willingham explains (referring to Simon, 1996), neuroscience can be considered a natural science with the general aim of discovering principles describing neural structure and function. Education however can be characterized as an artificial science aimed at creating artefacts (such as pedagogic strategies and materials) designed to serve a specific goal within a particular environment. In serving this goal (for example, providing children with knowledge), artificial sciences are normative rather than descriptive (Willingham, 2009). This distinction is useful to become aware of the difference in the type of questions neuroscience and education tend to ask, though it is not meant in this context to classify neuroscience and education as opposing types of sciences. The difference in type of questions is reflected in the conception of educational neuroscience either as a type of neuroscience or as a type of educational sciences.

It should be noted that we do not consider the two disciplines that we focus on here the only disciplines involved in educational neuroscience. Other disciplines or sub-disciplines can play important roles as well. Cognitive psychology, for example, has been suggested to provide two existing indirect paths (between cognitive psychology and education and between cognitive psychology and cognitive neuroscience) that might enable the collaboration between neuroscience and education (Bruer, 1997). Furthermore, a discipline such as psychology could provide a bridge between the types of sciences. However, the descriptions and examples below will make clear that the relations with neuroscience, educational sciences and educational practice are the main influence on the research questions that educational neuroscience asks. Relations or paths via other disciplines such as cognitive psychology could be included, but this would not result in a specific or additional position.

Below we will use several examples of studies or theory to clarify our descriptions of the three positionings. It should not be read, however, as a classification of the authors of these studies.

Educational neuroscience as part of neuroscience

Educational neuroscience can be regarded as a branch of neuroscience that investigates educationally inspired research questions (as formulated by Geake, 2011). This branch or neuroscientific perspective has several characteristics. First, research within this perspective concerns fundamental, but educational relevant constructs such as memory and learning (van Kesteren et al., 2012), sleep (van Dongen et al., 2012) or language switching costs (Grabner et al., 2012). For example, van Kesteren et al. (2012) describe a neuroscience study (using lesion and neuroimaging studies on humans and animals) on memory and learning. Their study focuses on the paradox that on the one hand new information is better remembered when it relates to existing knowledge (information congruent with existing schemas) and on the other hand novelty of information can improve learning (information incongruent with existing knowledge). A proposition is made for a framework able to reconcile these findings, based largely on findings in neuroscience. The conclusion, stating that “developments will be of fundamental importance for optimizing life-long learning and education” (p. 217), suggests that the topic of (the optimisation of) memory and learning is highly relevant for education and that the findings of this neuroscience study extend existing information that could be used in educational settings. Second, research in this perspective can concern (constructs underlying) specific learning disorders such as dyslexia (for example Butterworth et al., 2011) or dyscalculia (for example Gabrieli, 2009). As Butterworth et al. (2011) describe, neuroscience structural and functional imaging research on the bases of numerosity processes has extended the understanding of dyscalculia and its underlying cognitive deficits. In addition, this research provided valuable infomation for understanding general mathematics. The findings suggest approaches for improving mathematics learning and for specific interventions. These approaches address different constructs in comparison to traditional approaches on improving mathematical understanding. "An understanding of how the brain processes underlying number and arithmetic concepts will help focus teaching interventions on critical conceptual activities..." (Butterworth et al., 2011, p. 1053). The relevance for education is somewhat more explicit in this example than in the example above (van Kesteren et al., 2012), and seems to lie in providing information to increase understanding of (deficits in) mathematical reasoning.

Educational neuroscience can in this conception be characterized as neuroscientific research, as the approach, design and methods of these examples show. In addition, these approaches are used to answer questions that are in themselves of a fundamental neuroscientific nature (for example a question on the neural basis of numerosity processing). Or, referring to Willingham (2009), these questions and studies aim to discover, understand and describe neural structures and functions. What makes this type of neuroscience educational neuroscience is that (insights on) these neural structures and functions can be meaningful or relevant for education since they concern core concepts of education. The connection to educational sciences therefore lies in providing information or insights that educational sciences can further use or interpret. However, it should be made clear that this further use or interpretation by educational sciences (as well as the possible implementation in educational practice) is not described in the examples of this conception of educational neuroscience. The way both educational sciences and educational practice could use these findings does not seem to be part of the scope of these specific studies. The example on mathematics and dyscalculia by Butterworth et al. (2011) explains how neuroscience provides information on the specific constructs in which children with mathematical difficulties can be distinguished. This, as is argued, offers a clear indication for cognitive targets for mathematical instruction and intervention. Although this suggests the relevance of these neuroscientific findings for education, it is also made clear that further steps are necessary before this can be implemented in educational practice; "although the neuroscience may suggest what should be taught, it does not specify how it should be taught" (Butterworth et al., 2011, p. 1051). The example of this article shows how a distinct line is drawn between what the studies in this article strive to contribute to (provide information on which core constructs could be targeted in improving mathematical abilities) and what not (provide information on how these constructs could be targeted, how interventions would look like or how they should be implemented by teachers). The transfer of findings to education, in the sense of informing educational practice and teachers, appears to fall in the latter category.

Educational neuroscience as part of educational sciences

Studies in which educational neuroscience is presented as an integral part of educational sciences explicitly include this detailed consideration of the usefulness and relevance of their findings for education. This conception is suggested for example by De Smedt and Grabner (2015, forthcoming) describing the applications of neuroscience for mathematics education. For neuroscientific data on mathematical skills to be truly relevant for education, they stress, an explicit consideration of the learning context is crucial both in acquiring and in interpreting these data (De Smedt and Grabner, 2015, forthcoming). Moreover, the research questions in this conception contain this element of education and are aimed at creating a pedagogic strategy or material, with an explicit goal in an explicit (learning) environment in mind (the normative aspect of artificial sciences, Willingham, 2009). In the research approach, neuroscientific data are used in combination with data and theories from other disciplines of educational sciences (Ansari et al., 2012; De Smedt and Grabner, 2015, forthcoming). "Neuroscience data can deepen our understanding of the cognitive constraints in the learner and learning process, but they do not directly determine how instruction should be designed to optimally foster this learning". "Educational research should therefore combine available neuroscientific data with domain-general and domain specific theories of instructional design into new learning environments" (De Smedt and Grabner, 2015, forthcoming).

The difference between this conception of educational neuroscience and the conception described above becomes clear when we compare the examples on mathematical reasoning. As we saw, in educational neuroscience integrated in neuroscience, research can take the form of a neuroimaging study aimed at gaining knowledge in core structures involved in numerosity processing. When educational neuroscience is integrated in educational sciences, however, this research would be conducted both with a specific educational aim and an explicit consideration of constraints and possibilities of the context in which findings could be implemented. For example, the aim of the study would be to design an intervention directed at the core element of numerosity processing. Furthermore, attention would be paid to the age of the children the intervention would target, their attention span and the size of their class and possibilities of their teacher. The transfer of findings to educational sciences and educational practice is therefore an integral part of the research in this second conception of educational neuroscience. This relevance takes form through the entire research process, starting with the aim and research question. Moreover, this implies that theoretical aspects of education have to be taken into account as well, such as the conception, meaning, aims and ideals of education, as well as ethical implications of educational neuroscience.

This conception of educational neuroscience in which an active role of educational sciences is emphasised seems in line with what has recently been proposed in the discussion on educational neuroscience as a two-way, bidirectional collaboration between education and neuroscience (Ansari et al., 2011; Varma et al., 2008). This perspective has been proposed in response to a critical reflection on the contributions and perceived values of both neuroscience and education (as described by, for example, Ansari et al., 2011; Varma et al., 2008). The relative dominance of neuroscience and more contextual role of education as well as the resulting asymmetrical relation between neuroscience and education has been criticised (Ansari et al., 2011; Geake, 2011; Samuels, 2009; Varma et al., 2008). The emphasis on a more active role for educational sciences in educational neuroscience parallels our description of educational neuroscience as part of educational sciences.

Educational neuroscience as independent discipline

Finally, a third option for the positioning of educational neuroscience should be mentioned. In this conception of the field, educational neuroscience is not part of either neuroscience or educational sciences but is a separate and independent discipline. This has recently been described as a new, re-conceptualization of the field (Pincham et al., 2014), but has been suggested previously in a more implicit way (for example Ansari et al., 2012; Ansari and Coch, 2006).

Educational neuroscience as an independent discipline is described by Pincham et al. (2014) as consisting of uniquely trained “dual research scientists”. Although these scientists possess knowledge both on neuroscientific and on educational research techniques, their main expertise lies in the translation or assessment of neuroscience research for education: “at the heart of our approach is then the notion that the educational neuroscientist not only engages in neuroscience research, but also assumes responsibility for translating that research or assessing it’s educational applicability” (p. 29) and “..., the utility of neuroscience within the school context would become these academics’ primary focus” (p. 30). This conception of educational neuroscience is proposed in response to difficulties in translation and com- munication between neuroscience and education. It is claimed (though this is not very well substantiated) that it has already become clear that educational neuroscience as a “bridge between the disciplines is not sustainable” (Pincham et al., 2014, p. 29). The formation of a new autonomous field parallel to the existing fields of neuroscience and educational sciences is therefore proposed as a solution to difficulties in translation and communication. These difficulties would be solved, since professionals of this new autonomous field are specifically trained in these two skills (“if researchers are trained as educational neuroscientists, translation should not be a problem”, p. 30).

This conception of educational neuroscience strongly resembles the second option described. Here too, education is implicated in the entire research process, and the transfer of findings to educational practice is an integral part of this process. However, a closer look at how this connection to education emerges reveals an important distinction. When educational neuroscience is part of educational sciences, it connects to educational sciences by operating as an integral part of it. Educational neuroscience is one sub-discipline of educational sciences, as for example philosophy of education is as well. The transfer to educational practice therefore is made by educational neuroscience in the same way this transfer has always been (attempted to be) made by educational sciences and in which educational sciences has expertise. When educational neuroscience is an independent discipline, however, it connects to educational sciences by operating parallel to it. Educational neuroscience consequently transfers to educational practice independently and in its own way. This is in fact a, or the, specialty of the professionals of educational neuroscience as described by Pincham et al. (2014). This specialty of transferring to educational practice takes place in close collaboration with practitioners in all stages of the research process ("researchers and teachers work together to identify an educational need that neuroscience has the potential to help answer", "educational neuroscientists must work with educators to draw on the educator's wealth of practical knowledge regarding existing classroom practices and the feasibility of the proposed project"). This suggests what type of questions this third conception of the field aims to answer. Instead of considering the learning context or explicitly taking the learning context into account (as in the second option), the questions here are generated within and together with educational practice. Therefore, the questions, the research approach and the research professionals serve specific, concrete educational needs.

Positioning of the field and transfer

The descriptions above show the existence of educational neuroscience as part of neuroscience, educational sciences and as an independent discipline. These three conceptions of educational neuroscience are reflected in examples of research (in the cases of educational neuroscience as neuroscience and as educational sciences) or in a description of a proposed direction of the field (in the case of educational neuroscience as an independent field). Their differences lie in research questions, overall aim and approach as well as in possibilities and expectations.

This helps us to address our central point, i.e. the problems that can arise in the transfer of neuroscience insights into educational practice. As we saw in the option of educational neuroscience as neuroscience, limits are explicated in the possibilities of providing (and aiming to provide) concrete ideas or advice—although researches tend to suggest the possible relevance of constructs studied for education. A direct transfer of findings to educational practice is not the aim and should not be expected from these studies. Both when educational neuroscience is part of educational sciences and when educational neuroscience is an independent field however, the transfer of findings to educational practice is an integral part of the entire research process. Therefore, it is important and relevant for the discussion on the transfer of neuroscience findings to take these different conceptions of the field into account. This relevance becomes even more apparent when it is unclear which position is taken in or when the different positionings are blurred. For example, discussing educational neuroscience, Hardiman et al. (2012) note as a positive reflection on the field "interdisciplinary collaboration has yielded considerable educationally-relevant information about learning mechanisms that could not have been acquired solely through behavioral methods". But, as they continue more critically "teachers want more from the field of neuroeducation", and complaints from teachers are that "this research may seem highly relevant but is hard to apply in practice" (p. 136). The first, positive, note seems to reflect educational neuroscience as neuroscience. In the second, critical, note however, expectations are expressed that are not in line with this type of educational neuroscience. Whether these expectations (and therefore, this criticism) are justified depends on the position of educational neuroscience. Since educational neuroscience as neuroscience does not aim to directly apply findings to educational practice, this should not be expected. Another example is the concern expressed by Bakhurst (2008) that certain crucial aspects of education such as its values might be overlooked in educational neuroscience research. Such a concern might be justified and important, but the extent to which these aspects are explicitly taken into account in educational neuroscience research depends as well on the conception of educational neuroscience that is taken in. This mismatch between the aims studies have (and thus the positioning they take in) and what is expected from them is an important point. Transfer problems in the form of neuromyths and invalid brain-based teaching approaches can arise from this mismatch, for example when teachers attempt to meet their expectations from a specific study while this was not intended by the study. Furthermore, such a mismatch can contribute to a rejection of the possibility of educational neuroscience, when it is seen as an insurmountable problem or reflection of the incompatibility of the fields. Similarly, the criticism on the dominant role of neuroscience, which was referred to in a previous paragraph, is only justified if the aim and approach of educational neuroscience does not match this dominant role. When educational neuroscience is considered part of neuroscience, a more dominant role of neuroscience compared to the role of education can be valid.

Although we stress the validity of all three current options, a few comments can be made concerning this validity and the relation to transfer difficulties. First, we characterized the first option as being careful in setting limits regarding the aim of the research. However, it is important that researchers in these types of studies are at least aware how their statements remain prone to misinterpretation, even when they attempt to be clear on those limits. Therefore, it can be said that when neuroscientists conduct research on educationally relevant constructs (referring to this by educational neuroscience) transfer remains an issue. Researchers should see it as their responsibility to address this issue by stressing very clearly that it is not their aim to make this transfer, thereby explicitly restricting the scope of the findings. Second, concerning the second and third options, when the transfer to educational practice is considered part of educational neuroscience, it should be noted that the relationship between science and practice has always been difficult (Ansari et al., 2011; Coch and Ansari, 2012), especially in the field of education (Ansari et al., 2011). Connecting scientific findings or insights to educational practice has failed before, both because of simplistic assumptions about (problems in) educational practice and a reluctance amongst educators themselves, the latter stemming also from for example perceived irrelevance of research for the classroom and comprehensibility issues (Samuels, 2009). Therefore, further and more detailed consideration in both these approaches on how this transfer would take form is important. The claim by Pincham et al. (2014) that with specific training of professionals transfer would no longer be a problem might be too simple.

Third, in the description of educational neuroscience as an independent discipline, the recent proposition of this conceptualization by Pincham et al. (2014) was followed. It might be possible, however, to develop a different type of educational neuroscience as an independent discipline. As was mentioned, more implicit suggestions for such an independent field have been made. For example, Ansari et al. (2012) describe "interdisciplinary research" in the form of an "emerging field of translational research", also emphasising the importance of interdisciplinary trained translators (research practitioners). There appears to be a difference between the type of questions Ansari et al. (2012) suggest for neuro-educational research and the type of questions suggested by Pincham et al. (2014). Ansari et al. (2012) do not seem to suggest generating research questions with and within educational practice (as Pincham et al. do), but primarily emphasise the importance of translators who have knowledge of educational practice, instructional design and neuroscientific relevant findings.

Finally, we emphasise the importance of identifying the positioning of educational neuroscience. However, we do not consider the three options distinguished here fixed categories or the only, final directions for the field. As the example above on the difference between the suggestions of Ansari et al. (2012) and Pincham et al. (2014) makes clear, different elaborations of the three conceptualizations are possible, including the consideration mentioned earlier of additional disciplines such as cognitive psychology. Further, to clarify the three options, we gave examples of specific studies and theory. It is important to be aware that not all studies and theory necessarily match one option exactly and, as was already mentioned above, that these are examples of specific studies, not a classification of authors. In fact, authors can be seen to imply different conceptions of educational neuroscience in their studies and theory. For example, though we used the example of the paper by Butterworth et al. (2011) to illustrate the conception of educational neuroscience as neuroscience, a study of Butterworth and Laurillard (2010) on the same topic implies more of a conception of educational neuroscience as educational sciences. This confirms both the importance of being aware of and explicit in the positioning of a given study, and the view of educational neuroscience as a developing field, with researchers attempting to find its identity.

CONCLUSION

The transfer of thought and findings between neuroscience and education remains an important point in the discussion on educational neuroscience. Difficulties continue to emerge in this transfer in different forms—concrete confusions in the form of neuromyths and abstract confusions in the form of neuro-misconceptions. An example of a neuro-misconception is a confusion on the relation between the brain and the mind, which as we saw is sometimes not avoided in the case of children with deficits or disorders even if the misconception is acknowledged in case of typical children. These confusions can discredit the involved fields and can be used as part of an argument against the possibility and value of educational neuroscience.

We propose a consideration of the conceptual positioning of educational neuroscience since this positioning (referring to the respective relations between neuroscience, educational sciences and educational practice) relates directly to the issue of transfer. The relations between educational neuroscience and these other involved fields reflect and determine the nature of the questions educational neuroscience ask as well as the corresponding approach and methods to answer these questions. The difference between the distinguishable options for these relations (thus for the different positionings of the field) lies to a large extent in whether the transfer to educational practice is incorporated within these questions asked by the field and within the approach. Being explicit in which option is subscribed in studies or theory clarifies the aim of educational neuroscience and indicates what can be expected by and from the field.

We have described educational neuroscience as part of neuroscience, educational sciences and as an independent discipline. These descriptions showed three different but equally valid and valuable current options for educational neuroscience. We believe it is valuable to distinguish between these three options and to be aware of their implications for the transfer to educational practice. The examples that are given to illustrate the options confirm that taking one of these options is inevitable when conducting research that can be characterized as educational neuroscience. However, this does not imply that the options should be seen as final, fixed or static categories of educational neuroscience. Rather, they can be considered directions taken in while educational neuroscience is developing its own identity. To avoid blurring different positions and thus mismatching expectations, it is important for researchers to be explicit in the type of educational neuroscience they strive to conduct in specific studies or theory and to be aware of the implications of their choice and the expectations that are raised by it.

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