Psicología Educativa. Revista de los Psicólogos de la Educación
ISSN: 2174-0550
revistas_copm@cop.es
Colegio Oficial de Psicólogos de Madrid
España

Martín-Loeches, Manuel

Neuroscience and education: We already reached the tipping point

Psicología Educativa. Revista de los Psicólogos de la Educación, vol. 21, núm. 2, 2015, pp. 67-70
Colegio Oficial de Psicólogos de Madrid
Madrid, España

Psicología Educativa 21 (2015) 67–70

Psicología Educativa

www.elsevier.es/psed

Original

Neuroscience and education: We already reached the tipping point

Manuel Martín-Loeches*

Centro de Evolución y Comportamiento Humanos, UCM-ISCIII, Madrid, Spain. Departamento de Psicobiología, Universidad Complutense, Madrid, Spain

ARTICLE INFO

Article history:
Received 28 July 2015
Accepted 4 September 2015
Available online 9 October 2015

Keywords:
Neuroscience
Education
Brain maturation
Teaching

ABSTRACT

The aim of this contribution is to introduce the present Special Issue on Neuroscience and Education of the *Revista de Psicología Educativa/Educational Psychology*. After a brief introduction to current advances in general cognitive neuroscience that are being possible by means of brain imaging techniques available only during the most recent decades, we will discuss some aspects that have been contributing to hamper a true integration between both disciplines (neuroscience and education). The articles included in the present monograph provide empirical evidence that neuroscience has already reached a sufficient body of knowledge as to substantially improve education and political decisions in this respect. Neuroscience reveals that brain maturation extends at least until the second decade of life and that the exposition to different developmental experiences and opportunities is crucial along this extensive life period, so that none of its phases should be downplayed.

Neurociencia y educación: ya hemos alcanzado el punto crítico

Palabras clave:
Neurociencia
Educación
Maduración cerebral
Enseñanza

RESUMEN

Esta contribución pretende introducir y contextualizar el presente monográfico de la *Revista de Psicología Educativa/Educational Psychology* sobre neurociencia y educación. Tras introducir brevemente los avances que en neurociencia cognitiva, en general, se están alcanzando gracias a las técnicas de imagen cerebral disponibles sólo en las últimas décadas, se discuten algunos aspectos que han hecho difícil la verdadera integración entre ambas disciplinas (la neurociencia y la educación). Los artículos incluidos en este monográfico demostrarán que la neurociencia ofrece una cantidad más que suficiente de conocimiento acumulado como para aportar sustancialmente a la educación y a las políticas educativas. La neurociencia revela que la maduración cerebral no se alcanza hasta la segunda década de vida de la persona y que la exposición a diferentes experiencias y oportunidades de desarrollo es crucial a lo largo de toda esta extensa etapa vital, sin que debamos descuidar unos momentos más que otros.

Educational Neuroscience and Its Contribution to Education

Neuroscience is currently trendy, particularly the so-called *cognitive neuroscience*, the portion of neuroscience devoted to study the relationships between the nervous system and human cognition (Gazzaniga, Ivry, & Mangun, 2002). It is logical. Up to about 20 years ago, all evidence on the brain bases of human behavior was based on the study of anomalous or damaged brains, or with some outstanding developmental disorder. In the very last decades, however, and mainly by virtue of the advances in computational facilities, modern brain imaging techniques have conveyed a noticeable boost in the study of living, intact brains while persons perform any kind of mental or cognitive operation.

The improvement has been so noticeable that many topics traditionally viewed as 'taboo' in academic psychology are now being afforded by means of these techniques and with great success. Social interactions, consciousness, religion, moral, or artistic

* Corresponding author: Centro de Evolución y Comportamiento Humanos, UCM-ISCIII. Monforte de Lemos, 5, Pab. 14. Madrid, Spain.
E-mail address: mmartinloeches@edu.ucm.es

http://dx.doi.org/10.1016/j.pse.2015.09.001

appraisal are just a few of the many topics that are currently being possible to be objectively approached thank to the development of these techniques. As expectable, many of the goals attained in the area transcend to the public opinion, with great success. After all, cognitive neuroscience is facilitating the advancement in our understanding of us, while the human being is curious by nature. The big advantage of these technical developments is that they permit the objective study of these phenomena, surpassing the limitations of subjective access to information in course. Studies like those by Whalen and collaborators (e.g., Kim et al., 2010; Whalen et al., 2004), among many others, showing the capacity of the human brain to capture and process social information appearing less than 20 milliseconds and, therefore, out of conscious perception and control, are in my view outstanding examples of the type of findings that these techniques are making available. This entire endeavour is nevertheless just starting.

One of the oldest brain imaging techniques is *electroencephalography* (EEG) and its derived technique the *evoked or event-related potentials* (EP or ERP). Although it was originally developed in the twenties of the last 20th century, its applicability to studying numerous mental and behavioral phenomena has always been very limited until the advent of modern computation, which has permitted in the last decades treating huge amounts of EEG data in a sophisticated and complex manner. In turn, an easily available and low-cost technology has been able to grow as a powerful tool in the objective and quantifiable approach to human mind. To these advantages we should add its portability, so that we can study brain function in virtually any context. Its "sister" technique, the *magnetoencephalography* (MEG) is much less available and not at all portable. The most well-known technique, on the other hand, the trendiest one indeed – both in academic and in popular contexts – is the measurement of brain blood flow (which follows synaptic activations) through *functional magnetic resonance imaging* (fMRI). This technique exhibits a millimetre spatial resolution, while being much less invasive tan its sister technique the *positron emission tomography* (PET). Further, very recently, MRI has been developed (in its structural, i.e., non-functional version) as to approach valuable details of the numerous brain internal connections; we can therefore study individual neural circuits established along an individual's lifespan, which conveys important functional implications. Although fMRI is not a portable technique, in recent years a new and portable method is also available that permits the measurement of blood flow in the cortex in different contexts and situations, with higher degrees of ecological validity; this technique is known as *near-infrared spectroscopy* (NIRS). It is also relatively available, even if less than EEG. These are, overall, the main current neuroimaging techniques (for a review see, e.g., Crosson et al., 2011) that are currently shaking up the cognitive neurosciences.

But, as mentioned, even if there is already a big amount of data and studies with these techniques available – and there is currently a real explosion in this regard – we are only at the very beginning. This point is of relevance when we get into the topic of interest here, neuroscience applied to education, in order to better understand some of the current discussions.

In this regard, there is currently a hot debate, which started several years ago, on whether neuroscience is actually useful for education, whether the former really contributes to the latter (Ansari, Coch, & De Smedt, 2011). The debate is not finished at all but, as we will be able to notice in this special issue, it might be the moment to start closing it. Neuroscience has a lot to contribute to education, and in the future it will be increasingly the case of its contribution to this field of the highest relevance for human social, cognitive, and emotional development. For someone like the present author, who has been teaching basic neuroscience to students who will become teachers, the reach and the robustness of these arguments is of crucial relevance.

The Present Special Issue

On the one hand, as claimed by several authors (e.g., Willingham, 2009), neuroscience and education speak completely different languages and have different goals, so that they seem to belong to two totally different worlds. That is correct, and this has been indeed one of the very reasons for possible clash. In this regard, Janet Zadina proposes, in the first article of this special issue, the development of new specialists that are both neuroscientists and educators (Zadina, 2015). A wide and deep training in neuroscience, together with real and extensive practices teaching at school, is what the author proposes in the curriculum of a *cognitive neuroscientist*, a degree from which our society could earn large benefits. But even if this kind of specialization is still taking form or becomes established, it is not currently necessary to wait longer to see how neuroscience can help education. Zadina, as several other authors in the present issue, reckons a number of findings already achieved by neuroscience that are (or have the potential to be) directly beneficial for both educational policies and students' curricula. I totally agree with Zadina when she explicitly claims that it is not necessary to wait any longer for educational neuroscience to inform curriculum, "we have reached the tipping point".

In line with this, the next article in this special issue by Leisman, Mualem, and Mughrabi (2015), provides an extensive review on what neuroscience already knows about brain development, about the differences between critical and sensitive developmental periods as well as on how brain maturation emerges at different times in different brain regions. To do this, the authors use both current and past research, collected for more than a century of work in neuroscience since Ramón y Cajal's times. Genetics and epigenetics of brain development are treated in depth and assimilated in Leisman et al.'s paper. These authors stress in this respect how fundamental it is the complete – in all its potentialities – development of each brain region at its corresponding time, in order to be able to plainly further build up the next stages in cognitive, emotional, and social development.

A good example of how the most basic (perceptive and motor) processes are developed first and are needed working properly and suitably to base subsequent knowledge and developmental stages is provided in the article by Usha Goswami (2015), also in this issue. Indeed, the quality of information usually considered as basic will be conditioning the succeeding development of school processes as relevant as alphabetization. In addition, neuroscience has been able to unveil features of these processes that would not have been pondered as so crucial as they indeed are in absence of neuroimaging techniques. Namely, Goswami's work remarks the utility of EEG to determine the proficiency in sound, phonological, and prosodic segmentation of a child who still cannot talk, but of whom we could already say whether he or she will probably demonstrate difficulties when learning to read years later. Similarly, with this technique it is possible to objectively evaluate whether the different tasks and exercises that children play at school during early childhood, presumably enhancing children's phonological awareness as well as sound and linguistic segmentation (e.g., clapping out syllable rhythms in a song) are actually yielding the desired developmental effects. EEG appears therefore as a highly valuable tool both for early diagnosis and appropriate treatment, since neuroscience has shown that *dyslexia* is essentially predisposed by auditory aspects of language, these possibly carrying even much more weight than aspects of other modalities. Considering that in many hospitals it is currently routine to measure auditory capacity in newborns by means of a simple evoked potentials device (as mentioned, derived from EEG), it would not be out of place to see similar devices to easily measure at school the individual's brain capacity to synchronize to different acoustic and linguistic features. Subsequent school achievements would highly benefit.

But, as already remarked by Leisman et al. (2015), the maturation of the nervous system extends very far beyond the first 3 years of life, as traditionally claimed. The latter assertion was derived from animal studies; to the extent that the study of the living human brain has been possible thanks to the development of brain imaging techniques, the state of affairs has turned a little more complex. Neuroscience has been able to establish, in this regard, that brain maturation in human concerns the two first decades of life. This is further emphasized by Lipina and Segretin (2015) in the following article in this special issue, proposing that to "the first 1000 days" as crucial for brain development we should add up 6000 additional days. The centrality of this point is of the highest interest for educational policies and for preventing failure at school, as well as for the cognitive and emotional development of the child. For this reason, as stressed by Lipina and Segretin, intensive programs aimed at compensating the effects of poverty on cognitive and emotional development should be extended far beyond the first thousand days in a child's life. The authors present empirical evidence supporting this proposal. They show, in addition, that although maturation delays occurring in the following 6000 days are not necessarily irreversible, compensating their effects requires big effort, something to which in turn most of these children will not have access.

The special issue ends with two complementary articles demonstrating what the processes of brain maturation shortly before reaching the second decade of life are. During adolescence, and contrary to what is usually believed, the determinant factors are not necessarily hormones or contextual and social vicissitudes as such. Rather, during this period of life, which has normally received much less attention from an educational and pedagogical viewpoint than other, earlier periods, maturational processes are still in progress. Further, these maturational processes specifically concern brain regions that are critical not only for social cognition and self-consciousness, but for problem solving and abstract thinking as well, as remarked by Iroise Dumontheil (2015) in her article. The adolescence period becomes therefore crucial to plainly accomplish the brain faculties of an adult, and therefore what occurs during this period should be of the highest educational interest. Dumontheil (2015) shows that adolescents exhibit "over-mentalising", that is, their social cognition and their attribution of intentions – in other words, their "theory of mind" – is extremely alert, needing bigger efforts in order to achieve the same proficiency of an adult. This is supported by hiperactivations in adolescents of specific portions in the prefrontal cortex during the "Director" task, which explores the capacity to shift the viewpoint and that can be suitably studied in fMRI contexts. Plain performance in theory of mind is therefore not fully developed until adulthood, being in turn a crucial factor in achieving optimal and complex cognitive proficiency as adults (Gamble, Gowlett, & Dumbar, 2014). In a complementary line, the article by Catherine Sebastian (2015) extends these data, applying different experimental paradigms that permit to study in depth the degree of development in theory of mind and, particularly, responses to social rejection. The latter is approached in fMRI environments through the "Cyberball" paradigm, in which the recorded participant is systematically excluded by two other (virtual) players in a simulated game. The results again point to portions of the prefrontal cortex as fundamental for these processes, showing how the brain of adolescents is still immature in brain regions that are critical for most complex cognition, decision taking in diverse contexts, and even for individual liberty as a person. Overall, there is no cognition without emotion, as supported by neuroscientific evidence (Pessoa, 2013), and a correct balanced interaction between these two domains is fundamental to achieve all the potentialities of the human brain. Experimental results show how the adolescent's brain is, in this regard and in the words of Sebastian, a 'fast car with poor brakes'.

In conclusion, the contributions in this monograph – for which we are really thankful to all the authors – provide definite evidence on the relevance of neuroscience for educational and pedagogic matters, even in its current state. It is not necessary to wait any longer; there is already sufficient neuroscientific knowledge. The most exhilarating is, however, that the future of educational neuroscience appears highly fruitful and promising.

Resumen extenso

La neurociencia está de moda, y especialmente la así llamada "neurociencia cognitiva", la parte de la neurociencia que se dedica específicamente al estudio de las relaciones entre el sistema nervioso y la cognición humana (Gazzaniga et al., 2002). Es lógico. Hasta hace unos 20 años, toda evidencia científica acerca de las bases cerebrales o neurales de nuestro comportamiento venía del estudio de cerebros con alguna anomalía, bien por lesión, bien por alteraciones notables del desarrollo cerebral o en el transcurso de una operación a cerebro abierto. En las últimas décadas, coincidiendo en gran medida con el desarrollo de la tecnología informática, también llamada "la tercera revolución industrial", las técnicas de neuroimagen han supuesto un impresionante impulso para el estudio del cerebro vivo, sin tocarlo, mientras la persona realiza todo tipo de actividades mentales o cognitivas.

Tal ha sido el impulso, que muchos temas que tradicionalmente se han considerado "tabú" dentro de la psicología se están abordando mediante estas técnicas con gran éxito. Las interacciones sociales, la conciencia, la religión, la moral o la percepción artística son sólo algunos de los muchos tópicos que se están pudiendo abordar de manera objetiva gracias al desarrollo de estas técnicas. Es normal que muchos de los logros alcanzados trasciendan a la opinión pública y tengan gran éxito. No en vano, la neurociencia cognitiva nos está permitiendo avanzar en nuestro conocimiento sobre nosotros mismos, sobre nuestra propia esencia, y el ser humano es curioso por naturaleza. La ventaja que tienen estos avances es la de poder estudiar todos estos fenómenos de manera objetiva, superando las limitaciones de un acceso subjetivo a la información en curso. Estudios como los del grupo de Whalen y colaboradores (e.g., Kim et al., 2010; Whalen et al., 2004), entre otros muchos, que demuestran la capacidad de nuestro cerebro para captar información social que aparece durante menos de 20 milisegundos y, por tanto, totalmente fuera de nuestro control y alcance consciente, son para mí un gran ejemplo de lo que nos están permitiendo estas técnicas.

Pero por muy cuantioso que sea el número de trabajos realizados hasta la fecha mediante estas técnicas –y está habiendo en estos momentos una verdadera explosión– estamos sólo al principio. Este dato es importante a la hora de adentrarnos en el campo que aquí nos ocupa, la neurociencia aplicada a la educación, y entender algunas de las discusiones actualmente en boga.

En este sentido existe un enconado debate, abierto desde hace años, respecto a si realmente es útil la neurociencia para la educación, si aquélla aporta algo de utilidad para ésta (Ansari et al., 2011). El debate no está cerrado del todo pero, como tendremos ampliamente la oportunidad de comprobar en este monográfico, se podría ir dando por zanjado. La neurociencia tiene mucho que aportar a la educación, y en el futuro aún tendrá mucho más que aportar a este campo tan importante del desarrollo social, cognitivo y emocional del ser humano. Para alguien como este autor, que lleva más de una década enseñando nociones básicas de neurociencia a estudiantes que serán futuros maestros, el alcance y la solidez de nuestros argumentos resultan de crucial importancia.

Por un lado, como sostienen ciertos autores (e.g., Willingham, 2009), neurociencia y educación hablan dos lenguajes distintos y tienen objetivos distintos, de manera que parecen pertenecer a dos mundos distintos. Es cierto, y precisamente esta ha sido una de las razones de un posible desencuentro. A este respecto, Janet Zadina propone, en el primer artículo de este monográfico, la creación de una especialidad en la que los profesionales que salgan sean a la vez neurocientíficos y educadores (Zadina, 2015). Una formación amplia, profunda y suficiente en neurociencia, junto con la realización de prácticas reales y cuantiosas de enseñanza en las escuelas es lo que esta autora propone como formación para el *neurocientífico educativo*, una titulación de la que nuestra sociedad podría obtener grandes beneficios. Pero mientras esta titulación cobra cuerpo o se establece, no sería necesario esperar más para ver los beneficios que la neurociencia puede aportar ya a la educación. Zadina, al igual que otros autores del presente monográfico, enumera una serie de conocimientos que ya se han alcanzado por parte de la neurociencia y que tienen (o pueden tener) beneficios directos en las políticas educativas y en los currículos de los alumnos. Para Zadina, y no puedo estar más de acuerdo, ya no hace falta esperar más: los neurocientíficos, junto con otros profesionales cualificados, ya deberían formar parte de los grupos que toman las decisiones a este respecto, muy por delante de políticos o intereses económicos. No es pronto para que esto ocurra, "ya hemos llegado al punto crítico" (Zadina, 2015).

Los artículos incluidos en el presente monográfico muestran multitud de evidencias en este sentido. El artículo de Leisman, Mualem y Mughrabi (2015) aporta un extenso repaso de lo que la neurociencia sabe hoy día acerca del desarrollo del cerebro, de las diferencias entre períodos críticos y sensibles y de cómo la maduración cerebral se da en distintos momentos para las distintas regiones. Un buen ejemplo de cómo los procesos más básicos (perceptivos y motores) se desarrollan en primer lugar y se necesita de su correcto y completo desarrollo para fundamentar conocimientos y etapas de desarrollo subsiguientes lo tenemos en el artículo de Usha Goswami (2015), también en este número. Efectivamente, la calidad de la información que consideramos básica será determinante en el desarrollo posterior de procesos escolares tan relevantes como la alfabetización. La neurociencia también ha permitido establecer que la maduración cerebral en el humano abarca las dos primeras décadas de vida. En este aspecto insisten Lipina y Segretin (2015) en el siguiente artículo del monográfico, proponiendo que a los tradicionales "primeros 1000 días" de vida como período de suma importancia para el desarrollo cerebral de una persona habría que añadir otros 6000 días más. La relevancia de esta cuestión es capital para las políticas educativas y de prevención del fracaso escolar y el desarrollo cognitivo y emocional del niño. El monográfico termina con dos artículos complementarios que ponen en evidencia cuáles son los procesos de desarrollo madurativo del cerebro que se dan poco antes de alcanzar la segunda década de vida. En la adolescencia, contra lo que se suele creer, no son necesariamente las hormonas los factores determinantes, ni los cambios contextuales o sociales en sí mismos. Durante esta etapa de la vida, a la que quizá se le haya prestado menos importancia desde el punto de vista educativo y pedagógico, se producen maduraciones cerebrales que son clave no sólo para la cognición social y la autoconciencia sino para la resolución de problemas y el pensamiento abstracto, como afirman Iroise Dumontheil (2015) y Catherine Sebastian (2015) en sus artículos.

No es necesario esperar más, ya hay suficiente conocimiento útil acumulado. Lo ilusionante es, además, que el futuro de la neurociencia educativa se antoja sumamente fructífero y prometedor.

Conflict of Interest

The author of this article declares no conflict of interest.

Acknowledgements

The author has been awarded grant PSI2013-43107-P from the Ministerio de Economía y Competitividad (MINECO, Programa Estatal de Investigación Científica y Técnica de Excelencia, Subprograma Estatal de Generación de Conocimiento Proyectos de I + D), Spain.

References

Ansari, D., Coch, D., & De Smedt, B. (2011). Connecting education and cognitive neuroscience: Where will the journey take us? *Educational Philosophy and Theory*, *43*, 37–42.

Crosson, B., Ford, A., McGregor, K. M., Meinzer, M., Cheshkov, S., Li, X., & Briggs, R. W. (2011). Functional imaging and related techniques: An introduction for rehabilitation researchers. *Journal of Rehabilitation Research & Development*, *47*, vii-xxxiv.

Dumontheil, I. (2015). Development of the social brain during adolescence. *Psicología Educativa*, *21*. http://dx.doi.org/10.1016/j.pse.2015.08.001

Gamble, C., Gowlett, J., & Dumbar, R. (2014). *Thinking Big: How the Evolution of Social Life Shaped the Human Mind*. London: Thames and Hudson Ltd.

Gazzaniga, M. S., Ivry, R., & Mangun, G. R. (2002). *Cognitive Neuroscience: The Biology of the Mind*. New York: W.W. Norton.

Goswami, U. (2015). Neurociencia y Educación: ¿Podemos ir de la investigación básica a su aplicación? Un posible marco de referencia desde la investigación en dislexia. *Psicología Educativa*, *21* http://dx.doi.org/10.1016/j.pse.2015.08.002

Kim, M. J., Loucks, R. A., Neta, M., Davis, F. C., Oler, J. A., Mazzula, E. C., & Whalen, P. J. (2010). Behind the mask: the influence of mask-type on amygdala response to fearful faces. *Soial, Cognitive and Affective Neuroscience*, *5*, 363–368.

Leisman, G., Mualem, R., & Mughrabi, S. K. (2015). The neurological development of the child with the educational enrichment in mind. *Psicología Educativa*, *21* http://dx.doi.org/10.1016/j.pse.2015.08.006

Lipina, S. J., & Segretin, M. S. (2015). 6000 días más: evidencia neurocientífica acerca del impacto de la pobreza infantil. *Psicología Educativa*, *21* http://dx.doi.org/10.1016/j.pse.2015.08.003

Pessoa, L. (2013). *The Cognitive-Emotional Brain: From Interactions to Integration*. Cambridge, MA: The MIT Press.

Sebastian, C. (2015). Social cognition in adolescence: social rejection and theory of mind. *Psicología Educativa*, *21* http://dx.doi.org/10.1016/j.pse.2015.08.004

Whalen, P. J., Kagan, J., Cook, R. G., Davis, F. C., Kim, H., Polis, S., & Johnstone, T. (2004). Human amygdala responsivity to masked fearful eye whites. *Science*, *306*, 2061–2065.

Willingham, D. T. (2009). Three problems in the marriage of neuroscience and education. *Cortex*, *4*, 544–545.

Zadina, J. (2015). The emerging role of educational neuroscience in education reform. *Psicología Educativa*, *21* http://dx.doi.org/10.1016/j.pse.2015.08.005