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Conceptions and misconceptions about neuroscience in preschool teachers: a study from Argentina

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ABSTRACT

Background: Teachers' conceptions and misconceptions about neuroscience are crucial in establishing a proper dialogue between neuroscience and education. In recent years, studies in different countries have examined primary and secondary school teachers' conceptions. However, although preschool education has proved its importance to later academic outcomes, there is limited investigation of neuroscience conceptions focused exclusively on preschool teachers.

Purpose: The present study sought to explore preschool teachers' conceptions and misconceptions about neuroscience in an Argentine setting.

Sample, design and methods: We used quantitative and qualitative approaches to explore concepts about neuroscience, including specific neuromyths. Data were collected using a 24-statement questionnaire and 5 in-depth interviews. The survey was administered to 204 teachers of children between the ages of 0–5-years in Argentina.

Results and conclusions: Results from this exploratory study suggested a relatively high level of general knowledge of neuroscience amongst the preschool teachers in the study. However, three particular issues seemed unclear for teachers: memory, plasticity and the myth that 'we only use 10% of the brain'. Specifically, 'memory' was understood as 'learning by heart'; neural underpinnings of memory and plasticity processes were unknown; and the myth that we only use 10% of the brain was used to explain individual differences in intelligence in a straightforward way. In addition, anecdotal evidence was used by teachers to justify their conceptions about neuroscience. Finally, the wider implications of these results for bridging neuroscience and education are discussed.

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Neuromyths; neuroscience; education; mixed methods; preschool teachers

Introduction

Since the interdisciplinary dialogue between neuroscience and education started to gain increasing significance (Bruer 1997; Horvath and Donoghue 2016; Howard Jones 2014; Sigman et al. 2014), there has been growing concern about the prevalence of misconceptions about the brain and belief in what have been termed 'neuromyths' in the realm of education. In 2002, the OECD's Brain and Learning Project defined neuromyths as 'misconceptions

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generated by a misunderstanding, a misreading or a misquoting of facts scientifically established (by brain research) to make a case for use of brain research in education and other contexts', thereby drawing attention to misconceptions and their effects (OECD 2002, 69). Because these eventual misunderstandings are related to teachers' conceptions, they may contribute to poor quality practices inside the classroom, from preschool to high school (Deligiannidi and Howard Jones 2012; Karakus, Howard Jones, and Jay 2015).

Different studies have identified neuromyths and misconceptions amongst teachers in the United Kingdom and the Netherlands (Dekker et al. 2012), Portugal (Rato, Abreu, and Castro-Caldas 2013), Brazil (Bartoszeck and Bartoszeck 2012; Silva, Zeggio Perez Figueredo, and Ekuni 2014), China (Pei et al. 2014), Turkey (Karakus, Howard Jones, and Jay 2015); Argentina, Chile, Perú, México, Nicaragua, Colombia and Uruguay (Gleichgerrcht et al. 2015). Some of these studies have identified the reasons behind the prevalence of misconceptions and for higher rates of beliefs in neuromyths. For instance, in the United Kingdom and the Netherlands, teachers' general knowledge of neuroscience predicted an increased belief in neuromyths, especially in those related to commercialised educational programmes (Dekker et al. 2012). Another study that was carried out in Portugal showed that neither the teaching area of specialisation (e.g. mathematics, language) nor the level of teaching (e.g. primary school, secondary school), was related to neuromyths beliefs (Rato, Abreu, and Castro-Caldas 2013). A recent study with Latin American teachers (Gleichgerrcht et al. 2015) indicated that belief in neuromyths do not change depending on the level of teaching; nonetheless, higher education teachers showed a slightly superior general neuroscience knowledge. This could be thought of as expected, taking into consideration the higher rate of specialised topics in natural sciences in higher levels of education, and the more specialised and updated training that these teachers tend to receive. However, there are still relatively few studies that approach this and other potential reasons for misconceptions. For example, since teachers' professional development can change the degree of knowledge in neuroscience (Dubinsky 2010) teacher education becomes an important potential area for neuroscience knowledge to be studied within. In addition, it has been proposed that some factors serve to effectively protect neuromyths from the evidence that would be required to eliminate them, for example: (a) complexity of scientific concepts; (b) hidden evidence available only in technical journals; (c) technical jargon; and (d) the fact that some neuromyths are not readily testable. In this sense, the combination of these factors with emotional (e.g. wishful or anxious thinking) and cultural (e.g. religious or spiritual) considerations could contribute to the persistence of neuromyths (Howard Jones 2014).

Despite the fact that teachers' misunderstandings about neuroscience concepts have been identified across a range of countries, there are differences in prevalence between them (Gleichgerrcht et al. 2015; Karakus, Howard Jones, and Jay 2015; Pei et al. 2014). This supports the general hypothesis that culture could influence the types of neuromyths that become prevalent in a particular country. However, the specific reasons for such differences remain unclear.

There are some other studies that explore conceptions and misconceptions on neuroscience in Latin America countries. For example, Herculano-Houzel (2002) conducted a survey exploring what the Brazilian public knew about current findings in brain research. Results suggested that knowledge varied depending on the issue addressed; and that it increased with schooling and reading of science magazines and newspapers. Bartoszeck and Bartoszeck (2012) explored how secondary school Brazilian teachers perceived connections between education and neuroscience. They concluded that teachers believed that neuroscience may

contribute to the teaching and learning of their curriculum subjects. However, in that study, only 24 teachers were preschool teachers (teachers of 0–5-year-old children) and their responses were not analysed separately from the responses of teachers from other levels of teaching. Recently, Silva and colleagues (2014) studied the prevalence of neuromyths in a sample of educational psychologists, and primary and secondary school Brazilian teachers whilst Gleichgerrcht et al. 2015identified misconceptions about neuroscience amongst Latin American teachers, especially in terms of factual information about brain structure and functioning. In general, differences in neuroscience knowledge amongst countries tend to be observed, and it seems that teachers working in higher education evidence more conceptions in line with the current neuroscientific evidence. Interestingly, teachers from all levels who claimed they know more about the brain were more likely to believe in neuromyths.

Even though some of the studies mentioned above include preschool teachers in their sample (i.e. Bartoszeck and Bartoszeck 2012; Gleichgerrcht et al. 2015), we believe that insufficient attention has been paid to the prevalence of misconceptions amongst preschool teachers in particular. We would argue that this lack of focus on preschool teachers needs to be addressed, especially as a substantial body of research indicates that preschool education can improve the learning and development of young children (Barnett 2008, 2011). Specifically, preschool education has demonstrated its importance for school adjustment and academic skills in primary school, as well as its long-term effects for the quality of life (Magnuson et al. 2004; Yoshikawa et al. 2013). In Latin America, preschool education has assumed major importance, since there is a high rate of children attending school (reaching 81% of the age group by 2010) and it has been permanently increasing during the last 15 years (in part because in most countries preschool education is obligatory from the age of four and there is social pressure for preschool educational services [Itzcovich 2013]).

However, the quality of preschool education is variable and quality of teacher training has been proposed as a central factor in such variability (Whitebook 2003). In Argentina, educational preparation to become a preschool teacher begins after high school, lasts four years, is not degree level and does not vary depending on the age groups teachers will have to deal with. This educational preparation contains a module on psychology, but it is focused on children's characteristics in terms of classical theories of developmental psychology, which does not include any developmental neuroscience perspectives (Diker 2001). That absence of background learning could perhaps be a facilitator for the formation of neuromyths and misconceptions about neuroscience in preschool teachers, which in turn, may have detrimental effects at other educational levels.

Another important issue in this area of research is the methodology used to analyse the creation of myths and misconceptions. Many studies evaluate teachers' conceptions through the use of closed response surveys. However, Pickering and Howard-Jones (2007) added a small number of in-depth interviews to clarify educators' views on the role of neuroscience in education.

Results from several studies in the area suggest that there is substantial interest from teachers in neuroscience, and the belief that they can enrich their practices based on this knowledge (Bartoszeck and Bartoszeck 2012; Dekker et al. 2012; Pickering and Howard-Jones 2007; Rato, Abreu, and Castro-Caldas 2013; Serpati and Loughan 2012). At the same time, in recent years there has been an increase of available information for teachers in neuroscience and education (Howard Jones 2014; Sigman et al. 2014). However, since an increase in neuroscience interest has been associated with an increment in the belief in neuromyths

(Dekker et al. 2012; Soni García and Howard-Jones 2016) it is crucial to explore teachers' conceptions in neuroscience in order to improve the communication between both disciplines. In addition, because preschool education has proved to be an important factor in school adjustment, as well as its long-term effects in quality of life (Yoshikawa et al. 2013), it becomes particularly important to explore, specifically, the misconceptions about neuroscience that preschool teachers may hold.

Purpose

In this context, we conducted a survey and five in-depth interviews with preschool teachers to explore Argentinian preschool teachers' conceptions and misconceptions about neuroscience.

Materials and methods

Participants

Participants were 204 preschool (age range of children defined as 0 (45 days)–5 year-olds) teachers (184 females, 1 male; the remainder did not report gender). The preschool teachers had a mean age of 42.08 (SD 8.51) and were employed by 17 different schools of the districts Nº 2 and Nº 7 of the City of Buenos Aires. The mean number of years of teaching experience within the sample was 14.63 (SD 8.98) years. Importantly, the preschool teacher educational programme has never included developmental neuroscience content (EFDDCE 2009). Therefore, despite the age range in the sample, all participants would have had similar educational preparation in terms of exposure to neuroscience content. Preschool teachers are also offered approximately 18 hours per year of optional in-service training, but it does not usually include neuroscience content (GCBA 2015).

Seven participants were teachers of children in classes of children aged 0–2-years; 13 participants taught classes for 2-year-old children; 16 taught 3-year-olds; 34 taught 4-year-olds and 49 taught 5-year-old children (the remainder did not report class age). Although the regional curriculum provides guidelines for each age group, all preschool teachers receive the same educational preparation and in-service training, because in Argentina teachers can be assigned to a different age group annually (GCBA 2015). In terms of position, 10 participants reported that they were working as principals, while 175 reported that they were working as teachers at the time of the survey (the remainder did not supply this information). Five of the participants (i.e. those who agreed to be re-contacted to talk further about the issues) were interviewed between four and five months after completing the survey. Those five participants were female.

Procedure

The principals at each school distributed print copies of the survey to their teachers, asking them to complete it (self-report) and return it to the researchers. The research was presented as a study of how teachers think about the brain and its relationship with learning. All teachers were informed about the objectives of the study and the names and e-mail addresses of researchers were provided in case the participants had any questions. Also, all participants were invited to leave their e-mail address for an invitation to participate in the in-depth interviews. The participation in the study was voluntary and anonymous.

For the in-depth interviews, the researchers contacted the five teachers who agreed by e-mail and arranged a telephone call. After being informed about the objectives of the interview, they gave their informed consent. Interviews were recorded and lasted one hour approximately. Questions were semi-structured, and the focus was on trying to find out why teachers had responded in a particular way in their survey responses.

Measures

A mixed methods approach was taken, using quantitative and qualitative measures.

Quantitative measures

The questionnaire consisted of 24 statements written in Spanish, which was the language of the sample. The questionnaire was developed by combining and translating statements used in previous studies (Herculano-Houzel 2002; Howard-Jones et al. 2009). Participants were asked to indicate their agreement or otherwise with the statements by selecting 'agree', 'do not know' or 'disagree'.

From the 24 statements of our survey, the first three refer to theoretical concepts and therefore were not considered 'correct' or 'incorrect' in the same way as the other 21 statements. However, those statements were part of a previous survey (items 14, 62 and 65 from Herculano-Houzel survey [Herculano-Houzel 2002]) with responses from neuroscientists; therefore, we were able to consider whether the teachers in our sample answered in line with the neuroscientific view or not. Statements 4–17 of our survey were based on Herculano-Houzel (2002), so we used that study to determine whether a given statement was 'correct' or 'incorrect'. Statements 18–21 of our survey were taken from Dekker et al. (2012) study. Although Dekker and collaborators did not detail how they determined the correctness of their answers, we followed Dekker and collaborators and other authors (Howard Jones 2014) in decisions about correctness, based on the evidence on plasticity across the life span (Ansari 2012; Cotman and Berchtold 2002; Mahncke et al. 2006).

Finally, three statements that were not used in previous studies were added and considered as follows. Item 22 (*The impact of poverty on brain development cannot be altered through educational interventions*) was considered false because of the evidence indicating that poverty effects can be limited by educational interventions (Blair and Raver 2016; Hackman, Farah, and Meaney 2010). Item 23 (*Intelligence is more important than motivation on children's academic outcomes*) was considered incorrect following evidence about other factors than intelligence that predict academic achievement (Jones and Bouffard 2012; Krapohl et al. 2014; Lee et al. 2012; Maddox and Markman 2010). Item 24 (*Teachers are responsible for part of the motivation that children display in the classroom*) was considered correct based on the evidence in favour of this statement (Cai et al. 2007; Gläser-Zikuda and Fuß 2008; Portilla et al. 2014; Sosic-Vasic et al. 2015). Table 1 details the survey questions.

We divided the statements into four main themes, based on the neuroscience literature. Statements 1–3 dealt with the concepts of mind and consciousness and their relation to the brain (e.g. 'The mind is a product of the work of the brain'). Statements 17, 18 and 20 included references to neuromyths (e.g. 'We only use 10% of our brain'). Another set of items (items 6, 7, 14–16 and 19–22) addressed the issue of plasticity (e.g. 'Learning occurs through the modification of neuronal connections') and lastly, statements 4, 5, 8, 9–13, 23 and 24 referred to specific cognitive or psychological processes as attention, memory or emotions

Table 1. The questionnaire statements (presented in Spanish in the study) used in this study and their sources.

	Statement and source of statement	Correct (C) Incorrect (I) Theoretical concept (T)
(1)	♦Mind activity can be studied through brain activity (HH)	T
(2)	The mind is a product of the work of the brain (HH)	T
(3)	Without a brain, consciousness is not possible (HH)	T
(4)	Our environment can influence the production of hormones and, in turn, influence personality (HH)	C
(5)	We use our brain 24 hours a day (HH, D)	C
(6)	♦Learning occurs through modification of neuronal connections★ (HH, D)	C
(7)	Performance in activities such as playing the piano improves in terms of hours of practice (HH)	C
(8)	We experience joy, anger and fear with the brain, not the heart (HH)	C
(9)	Hormones influence the internal state of the body, but not personality (HH)	I
(10)	Memory is stored in the brain as in a computer. That is, each type of memory goes into a tiny piece of brain. (HH)	I
(11)	Memory is stored in cellular networks distributed throughout the brain (HH, D)	C
(12)	♦Keeping a phone number in memory until it's dialled, remembering recent events and recalling distant experiences are different abilities of a single memory system. (HH)	I
(13)	♦When we sleep, the brain stops working (HH, D)	I
(14)	Learning is due to the addition of new cells to the brain (HH, D)	I
(15)	Brain activity depends entirely on the external environment: if there is no stimulation of the senses, then we do not see, do not hear or feel anything (HH)	I
(16)	♦Cognitive skills are inherited and cannot be modified by the environment or life experience (HH, D)	I
(17)	We only use 10% of our brain★ (HH, D)	I
(18)	Learning problems associated with developmental differences in brain function cannot be remediated by education★ (D)	I
(19)	The production of new connections in the brain can continue into adulthood (D)	C
(20)	♦There are 'critical periods' in childhood after which we cannot learn some things (D)	I
(21)	♦Sustained practices of some mental processes can change the shape and structure of some parts of the brain (D)	C
(22)	The impact of poverty on brain development cannot be altered through educational interventions	I
(23)	Intelligence is more important than motivation on children's academic outcomes	I
(24)	Teachers are responsible for part of the motivation that children display in the classroom	C

Notes: Bracketed letters indicate the studies which these statements are based on:
(HH) – Herculano-Houzel (2002).
(D) – Dekker et al. (2012)
★ – These statements have also been used in other studies (Bartoszeck and Bartoszeck 2012; Deligiannidi and Howard Jones 2012; Gleichgerrcht et al. 2015; Howard Jones 2014; Karakus, Howard Jones, and Jay 2015; Rato, Abreu, and Castro-Caldas 2013) but in all of them the consideration of correct/incorrect answers remains as in the ones presented in the table;.
♦ – These statements are slightly different from the ones used in other studies, due to the translation into the Spanish language for use in the study.

(e.g. 'Memory is stored in cellular networks distributed throughout the brain'). Correct and incorrect statements were balanced (to give 12 correct and 12 incorrect statements, assuming the inclusion of the theoretical concept items 1–3). As part of the survey, teachers were asked to provide information about their age, gender, level of teaching experience and specify the age group of the children attending the class they taught.

Qualitative measures

For the qualitative part of the study, we conducted semi-structured, in-depth interviews via a phone call. The objective of the interview was to know more about teachers' experience, their level of education, their interest in neuroscience, the sources of information about

neuroscience that they used, and their beliefs. The final theme of 'beliefs' was included because religious beliefs have been proposed as a mediator of neuromyth beliefs (Deligiannidi and Howard Jones 2012; Howard Jones 2014). The interview also sought to explore why teachers responded in a particular way to certain items (this varied depending on how each teacher completed the survey). The interviews had two parts: the first part was the same for all teachers, and the second was specific for each teacher and item. During the first part, rather than closed questions, we tried to explore certain areas of interest through open questions or asking for comments. We explored the following points: 1. Training and experience (e.g. we asked 'Please, tell us about your teacher training and experience'). 2. Neuroscience training ('Did you learn about neuroscience on your teacher training or in any course? Could you describe the experience?') 3. Neuroscience interest ('Are you interested in scientific knowledge about the brain? Why?') 4. Neuroscience contribution to practice ('Do you believe neuroscience research could help in your teaching activity? How?') 5. Neuroscience information resources ('How often do you read articles on neuroscience/watch neuroscience programmes or documentaries? Could you tell me about that or other contact you have with science?') 6. Religious belief ('How do you experience religion' or 'Please, tell us if you have any religious beliefs'). Follow-up questions that were asked included, for example, *Could you explain to me why in [X] item you answered I agree/I disagree/I don't know?*

All the telephone interviews were recorded and, later, transcribed for qualitative analyses.

Data analysis

In order to explore, quantitatively, the level of conceptions and misconceptions about neuroscience of the teachers included in the sample, we analysed frequencies of responses by statement and by theme. In addition, to examine which factors predicted those responses, we performed regression analyses. However, the results suggested that teachers' conceptions and misconceptions about neuroscience did not vary as a function of variables considered in the model and, further, indicated that none of the independent variables (*teachers' age*, *years of service* or *age of the children attending the teachers' class*) predicted the answer to any statement. Therefore, these additional analyses are not reported further in this paper (results are available upon request).

To analyse the in-depth interviews, we followed the guide for conducting thematic analysis proposed by Braun and Clarke (2006). As a first step, we transcribed the interviews and read them one more time to become familiar with the data. From doing that, we created a list of ideas to be explored. For the second step, to organise the ideas in meaningful groups, we generated initial codes (based on the previous list of ideas). Those codes were data-driven (ideas repeated across all interviews) and theory-driven (ideas to be explored). Third, those codes were grouped in the broader category of themes. We created a thematic map including themes (e.g. *the context*, *the Argentine preschool teacher*, *intelligence*, *education, religiosity, poverty, sources of information*), sub-themes (e.g. *memory*, *mind/brain relationship*, *health*, *misconceptions*) and codes (e.g. *high expectation from society*, *close relationship with parents*). In the fourth phase, we re-read the interviews to ascertain whether the themes corresponded well in relation to the data-set. In step five, we defined and named the themes. For each individual theme, we re-read the interviews and conducted an analysis to identify what teachers said about it, and generated conclusions based on the data.

Results

Teachers' conceptions and misconceptions about neuroscience

The analyses of teachers' answers to the questionnaire as a whole revealed that, in the case of half of the statements, around 70% or more of the respondents chose the response that was coded as the 'correct' (Table 2).

Analysis of the survey responses by theme showed that the three statements that dealt with theoretical concepts (i.e. statements 1, 2 and 3) were answered by more than 70% of the teachers in line with a scientific view (Herculano-Houzel 2002). Of these statements, item 3 ('Without a brain, consciousness is not possible') obtained the highest percentage of agreement (81%).

In relation to neuromyths, most teachers answered statements 18 and 20 correctly. The most prevalent neuromyth was statement 17 'We use only 10% of our brain': 40% of teachers

Table 2. Teachers' responses for each statement ($n = 204$).

Statements		Do not know (%)	Agree (%)	Disagree (%)
(1)	Mind activity can be studied through brain activity (T)	17	**73**	10
(2)	The mind is a product of the work of the brain (T)	13	**71**	17
(3)	Without a brain, consciousness is not possible (T)	10	**81**	10
(4)	Our environment can influence the production of hormones and, in turn, influence personality (C)	6	**79**	14
(5)	We use our brain 24 hours a day (C)	1	**95**	4
(6)	Learning occurs through modification of neuronal connections (C)	27	**59**	14
(7)	Performance in activities such as playing piano improves in terms of hours of practice (C)	3	**90**	7
(8)	We experience joy, anger and fear with the brain, not the heart (C)	7	**71**	22
(9)	Hormones influence the internal state of the body, but not personality (I)	11	28	**60**
(10)	Memory is stored in the brain as in a computer. That is, each type of memory goes into a tiny piece of brain (I)	24	**55**	21
(11)	Memory is stored in cellular networks distributed throughout the brain (C)	42	**49**	9
(12)	Keeping a phone number in memory until it's dialled, remembering recent events, and recalling distant experiences are different abilities of a single memory system. (I)	19	34	**47**
(13)	When we sleep, the brain stop working (I)	4	5	**90**
(14)	Learning is due to the addition of new cells to the brain (I)	25	9	**65**
(15)	Brain activity depends entirely on the external environment: if there is no stimulation of the senses, then we do not see, do not hear or feel anything (I)	7	15	**78**
(16)	Cognitive skills are inherited and cannot be modified by the environment or life experience (I)	2	6	**92**
(17)	We only use 10% of our brain (I)	34	**40**	26
(18)	Learning problems associated with developmental differences in brain function cannot be remediated by education (I)	20	22	**58**
(19)	The production of new connections in the brain can continue into adulthood (C)	30	**60**	10
(20)	There are "critical periods" in childhood after which we cannot learn some things (I)	16	20	**64**
(21)	Sustained practices of some mental processes can change the shape and structure of some parts of the brain (C)	**43**	35	22
(22)	The impact of poverty on brain development cannot be altered through educational interventions (I)	11	29	**61**
(23)	Intelligence is more important than motivation on children's academic outcomes (I)	3	10	**87**
(24)	Teachers are responsible for part of the motivation that children display in the classroom (C)	0	**93**	7

Note: The largest proportion of responses for each item is emboldened.

agreed with this incorrect assertion. In addition, 22% agreed with the incorrect statement 18: 'Learning problems associated with developmental differences in brain function cannot be remediated by education' and 20% agreed with the incorrect statement 20: 'There are "critical periods" in childhood after which we cannot learn some things'.

> In terms of the statements about plasticity, most were answered correctly by over half of the teachers. However, 43 per cent of the teachers answered '*I do not know*' to the assertion that *Sustained* practices of some mental processes can change the shape and structure of some parts of the brain. (statement 21)

Finally, regarding cognitive and psychological processes, most teachers answered all relevant statements correctly, with the exception of statement 10 'Memory is stored in the brain as in a computer', which 55% of teachers thought was correct. Statements about motivation (i.e. statements 23 and 24) were answered with high percentages of concordance with the correct response (87 and 93%, respectively). Statements 4 and 9, which dealt with the influence of hormones on psychological processes, also had reasonably high levels of agreement with the correct responses (79 and 60%, respectively). However, when it came to memory statements (statements10, 11 and 12), teachers showed lower percentages of concurrence with the correct answer: for each of these three statements, the proportion of teachers who selected 'do not know' and the incorrect answer was greater than the percentage of correct responses.

Qualitative analysis of in-depth interviews

Findings from the thematic analysis indicated some noteworthy patterns and common themes. Those patterns do not match exactly with the areas of interests that guided interviews, but emerge from the answers teachers gave about them. These findings are summarised below, with some extracts from the interviews included as examples. These interview extracts have been translated from the Spanish and anonymised in line with the study protocols.

(a) The Argentine context

All teachers considered that their role as a preschool teacher was demanding. Also, some described their role as one of assisting parenting, as illustrated in the following quotations from the interviewees:

> …it is often the case that at this level society expects the teacher to teach the children behaviours that are specific to parents and families. For example, the excretory functions, personal hygiene, washing their hands … a lot of issues that are more sanitary or for assistance purposes rather than educational.

> You can forget about being a kindergarten teacher if you haven't realised that you are working with the children and their parents.

(b) Sources of information

None of the interviewed teachers used any source of information to answer the questionnaire. However, when they had to look for information for their work, the sources of information they used were very variable: some of them only received information through in-service training, while others watched documentaries, read books or used the internet to look things up. For example:

> Yes, all the time! Yes, for example, during the weekend at 8PM in the Discovery or National Geographic channel, there is one [documentary] that studies brain function each season, sometimes in special needs and sometimes not … or they study topics related to memory. Really, everything that has to do with the brain interests me.

> For my job, in general, I do not search for information on the Internet. Only a very few times for issues of general information. For my job, information really gets through to me via in-service training.

(c) Mind/brain relationship

The interview data suggested that most teachers thought of mind and consciousness as brain processes. As one commented,

> Through a brain scan, while different mental operations are being carried out, such as recalling something or repeating word lists, you can see the brain areas being marked that are associated with each mental task.

(d) Neuromyths

It appeared that teachers utilised neuromyths to provide a straightforward comprehension of reality. Regarding the myth of 'We only use 10% of our brain', teachers gave an explanation in which they oversimplified brain functioning. The myth allowed them to explain brain functioning after brain lesions, as well as different levels of intelligence, as these quotations illustrate:

> In fact, people who had cerebrovascular accidents at a very young age can create new neural networks that substitute those. So, then I think if they can substitute the part that died and they do not lose any functions, then there are areas in the brain that can give more. It isn't the case that because they are substituting a part of the brain that died, it loses another one.

> If we used 100% we'd be too intelligent.

(e) Memory

Memory was understood as 'learning by heart', which means learning only by repeating content without understanding. Also, it was considered to be an inferior kind of learning. Teachers did not differentiate long-term memory from short-term memory, or show awareness of neurobiological systems of memory storage.

> One can learn by heart, exactly as is a phrase; and another thing is to learn from reasoning (…). One is rote learning, which maybe you are going to forget, and another is the learning that has to do with reasoning. By relating it to other things you have left over in memory.

(f) Plasticity

Cerebral mechanisms of plasticity were not deeply understood, and plasticity was viewed from a behavioural level:

> I think there are issues that are not directly modifiable, but they are malleable. I think you can help to change certain behaviours. From education one can help build learning and modify some attitudes that influence the process.

(g) Belief systems

The interviewed teachers defined themselves as believers in God (Catholic religion), but none considered themselves as practising.

> Overall, results of the findings from the qualitative analyses showed that preschool teachers' explanations of concepts or arguments were almost always based on first person anecdotal evidence. That is, they did not justify their responses on the basis of studies, or academic information but, rather, from personal views or observations. The following extract represents an example of anecdotal evidence observation used to make a judgement about an idea:
>
> I have proven in myself that vision is supplemented by references and by the prior knowledge and concepts and culture that the brain has. It happens to me that if I am distracted and I see an image, I do not interpret it.

Discussion

The first objective of the present study was to explore preschool teachers' conceptions and misconceptions about neuroscience. Preschool education deserves special consideration, since it is viewed as increasingly important in terms of the whole educational career. A substantial body of research establishes the importance of preschool education for later school and life success (Barnett 2008; Magnuson et al. 2004; Yoshikawa et al. 2013).

Our study suggests that preschool teachers in our sample showed a medium to high level of neuroscience awareness. The fact that in half of the statements 70% or more of respondents answered correctly indicates that the topics covered by this survey were, in general, fairly familiar to preschool teachers. The degree of general neuroscience awareness of the Argentine preschool teachers we sampled appears in line with previous findings about preschool-to-secondary school Argentinian teachers (Gleichgerrcht et al. 2015). Although making direct relationships between studies with different populations is clearly not appropriate, comparisons with the same items in previous studies suggests that preschool teachers in our sample show a relatively high degree of awareness and, it seems, one that is greater than that of primary and secondary teachers studied in Greece (Deligiannidi and Howard Jones 2012), Turkey (Karakus, Howard Jones, and Jay 2015) and the Netherlands (Dekker et al. 2012). Popular media has been proposed as a factor that could influence neuroscience knowledge (Howard Jones 2014) and it is certainly the case that neuroscience has an increasing presence in the Argentinian media. For instance, in recent years there have been television series on the topic of neuroscience; for example, 'The brain and me' (La Brújula 2014) and 'The enigmas of the brain' (Palma 2011). Articles on neuroscience also receive coverage in Argentinian newspapers (e.g. Bar 2013). Media could, therefore, have an impact on teachers' knowledge, independently from the teachers' formal training (this notion could be further explored in future studies, we suggest). Teacher training deserves special attention, since quality and length of preschool teachers' education could be a central factor in terms of neuroscientific knowledge. In Argentina, educational preparation (Diker 2001; EFDDCE 2009) and in-service training does not include neuroscience content. This fact not only became evident from analysing preschool teachers' educational programmes (EFDDCE 2009), but also was expressed by the interviewed teachers: none of them mentioned as resource of information in neuroscience the preschool teachers' preparation or in-service training. Therefore, presumably, the neuroscientific knowledge that the preschool teachers showed cannot be explained through those formal training mechanisms.

However, not all neuroscience issues were understood by the preschool teachers to the same degree. In response to some specific statements, we identified less than 50% of agreement with the correct response, suggesting that those particular issues are less clear for teachers and, therefore, should be targeted in future training for teachers. The statements with most incorrect or unknown answers were statements 10 ('Memory is stored in the brain as in a computer. That is, each type of memory goes into a tiny piece of brain'), 11 ('Memory is stored in cellular networks distributed throughout the brain'), 12 ('Keeping a phone number in memory until it's dialled, remembering recent events, and recalling distant experiences are different abilities of a single memory system'), 21 ('Sustained practices of some mental processes can change the shape and structure of some parts of the brain') and 17 ('We only use 10% of our brain'). Qualitative analyses support those results, suggesting that there are three broader areas that are unclear for preschool teachers: namely, memory, plasticity and the popular myth that we only use 10% of our brain.

Memory appears to be a crucial issue to be focused upon in future training for teachers, since all statements related to this cognitive process were answered correctly by less than half of the teachers. Also, as the qualitative analyses indicate, memory is understood as a short-term way of learning, with low durability. Specifically, the concept of memory is understood as 'learning by heart', a kind of learning that should not be promoted in school based on the available scientific evidence. It is important to consider this finding, since advances in memory research that have potential applications to education could be discarded by teachers because of this misunderstanding of the term. Actually, differences in terminology and language have been suggested as important obstacles in bridging the neuroscience and education gap (Howard Jones 2014). In addition, cultural conditions have contributed to a 'gap' between neuroscience and education that has shielded these distortions from scrutiny. Technical jargon is a barrier, as are the different meanings assigned to familiar terms as 'memory'. Therefore, it is important to clarify those terms. For example, it would be useful to generate interdisciplinary materials for teachers and neuroscientists, explaining the differences between those two concepts of memory too. Also, the study suggests that types of memory (short-term memory/long-term memory) and the mechanisms of memory at a neural level are misunderstood. Different possible explanations could be discussed, but the fact that the interviewed preschool teachers made it clear that they had not really considered the way in which memories are stored in the brain and retrieval from it, could indicate that those kinds of issues have been absent from preschool teachers' training. Besides that, the confusion mentioned about the term 'memory' and the other factors proposed by Howard Jones (2014) could also be contributing factors to the misunderstanding of the process.

In terms of the concept of plasticity, although the majority of the teachers considered that there were no critical periods and cognition is not inherited, they did not display an understanding of the brain as an organ. However, a noteworthy finding was that most teachers agreed with the idea that learning occurs through modification of neuronal connections. These findings, supported by the qualitative analyses, suggest that they know that there is a behavioural level of plasticity, but the neural bases for this phenomenon are not completely clear or known to them. These conclusions (in memory and plasticity) are similar to the ones obtained by Gleichgerrcht et al. (2015) in preschool, primary and secondary school teachers with respect to the empirical facts demonstrated by neuroscience.

In terms of neuromyths, Gleichgerrcht et al. (2015) reported a 50% prevalence of neuromyths in preschool teachers in a Latin American sample. In our Argentinian sample of

preschool teachers, we found a smaller percentage of beliefs in the same neuromyths. The neuromyth referring to the use of only '10% of the brain' was the most prevalent in our sample (40% agreed with this incorrect statement and 34% acknowledged they did not know). The myth of the '10% of the brain' gives a simple explanation for individual differences in cognition. The argument explained by the interviewed preschool teachers indicates belief in the idea that 'very intelligent persons', 'gifted children' or people with 'extra-sensorial perception' would use 100% of the brain. This assertion lets teachers explain, in a straightforward way, individual differences in cognition, without questioning their relation to current understanding of the brain. The simplicity of an argument, combined with a mass of anecdotal evidence, has been proposed as one of the ways that neuromyth beliefs are constructed and maintained (Howard Jones 2014).

Findings from the present study suggest that the majority of preschool teachers in our sample did not consider that mind and brain work separately, or are different entities. The same situation was apparent regarding emotions and the brain: most teachers agreed with the idea that the brain is responsible for our emotions. It is interesting to note that religious belief has been proposed as a cultural factor that can potentially bias educators' ideas about the mind–brain relationship (Deligiannidi and Howard Jones 2012; Howard Jones 2014). This is clearly an area worthy of further exploration with larger samples.

In terms of topics referring to cognitive and psychological processes, many teachers answered questions about motivation and influence of hormones correctly. They considered that environment can influence the production of hormones and that teachers are in part responsible for motivation children have. Those results suggest that this sample of preschool Argentine teachers considered, in line with scientific evidence, (a) environment–hormones–personality as malleable contents; and (b) motivation as a result of teacher–child interaction.

In summary, general knowledge of teachers varied according to the topic (e.g. plasticity, mind–brain relationship). While body/mind or brain/mind views were largely correct, we identified others issues in which neuroscience knowledge was limited or insufficiently clear (e.g. neural mechanisms of plasticity; neural underpinnings of memory). The same variation was found in the prevalence of neuromyths: while some neuromyths were clearly established, others had a smaller influence. In consequence, we would suggest that future work with teachers (i.e. in teacher training; classroom interventions), in order to benefit from the interaction between neuroscience and education, should consider that memory, neural plasticity and the popular myth that we only use 10% of our brain are themes that are especially prone to misunderstanding. For this reason, working on proper definitions of those concepts should be a first step to a productive dialogue. In addition, we would consider that it would be important to include these issues in future surveys exploring teachers' knowledge, in order to better understand how conceptions may change and develop.

Other results from the qualitative analysis that should be borne in mind are that all interviewed teachers gave anecdotal arguments to explain their answers. The use of empirical data to justify arguments is characteristic of the scientific method; however, this does not tend to play a large part in preschool teachers' training. The relationship between anecdotal evidence and scientific evidence is important. To differentiate between first-person anecdotal arguments and empirical data results should, we argue, continue to be an important factor in future interdisciplinary work in the neuroscience and education field.

It is important to note some limitations of this exploratory study. First, the questionnaire had only 24 statements, and clearly not all neuroscience contents can be summarised in this limited selection. In addition, there were three options for response, and therefore some correct selections will inevitably be by chance. In order to develop the use of the questionnaire further, it would be necessary to trial the questionnaire with larger populations and obtain measures of reliability and validity. To obtain more detailed information from our sample, we conducted five in-depth interviews, but the sample of interviewed teachers was small. The time constraints on the interviews meant that we could not explore all areas as deeply as we would have liked. Also, the interviewed teachers were the ones that volunteered to be interviewed because they might have been more interested in neuroscience than the other teachers were, we cannot assume that their answers were representative of the group.

Nonetheless, this study offers an analysis of data that focus on the neuroscience knowledge of preschool teachers in an Argentine setting. Quantitative and qualitative analyses has allowed us to identify topics that are well or, in contrast, poorly known in the population, establishing possible areas for future work with preschool teachers. Identifying the root of the misunderstandings, we would argue, is crucial in helping to support and develop relevant and effective training for preschool teachers

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