When I Met my brain: Participating in a neuroimaging study influences children’s naïve mind–brain conceptions

Sandrine Rossi, Céline Lanœ, Nicolas Poirel, Arlette Pineau, Olivier Houdé, Amélie Lubin

A R T I C L E   I N F O

Article history:
Received 7 February 2015
Received in revised form 7 July 2015
Accepted 8 July 2015
Available online 9 July 2015

Keywords:
Mind
Brain
Naïve conceptions
Children
MRI
Neuroeducation

A B S T R A C T

Children who participate in neuroimaging research most likely revise their naïve conceptions about the brain, the mind and their relation. Our aim was to explore this educational effect by comparing two groups of 8-year-old children with and without MRI experiences. Our Mind–Brain Questionnaire allowed us to explore the participants’ naïve conceptions through different cognitive functions. The results revealed that the MRI group had a better understanding than the control group of the relation between the mind and the brain, especially for mental functions (dreaming and imagining), suggesting that the control group had more difficulty materializing the mind into the brain. This relation was less clear for basic (seeing and talking) and scholastic (reading and counting) functions. These results suggest that information regarding neuroimaging studies offers a complementary brain education program that could be implemented in a pedagogical project to encourage opportunities for teaching developmental cognitive neuroscience in classrooms.

1. Introduction

In addition to contributing to the understanding of brain anatomy and functioning, developmental cognitive neuroscience research contributes to the link between the brain and education [1–7]. An increasing number of typically developing children have participated in neuroimaging protocols by lending their brains to science. This special experience gives them an opportunity to learn about their own brain. For children, being involved in neuroimaging studies is unusual and exceptional; it is a particularly magical experience about their own brain. For children, being involved in neuroimaging studies is unusual and exceptional; it is a particularly magical moment when they see images of their brain’s anatomy. By opening the door for them to learn about their learning organ, this scientific experience might contribute to revising children’s naïve conceptions about the mind, the brain and their relation (hereafter, naïve mind–brain conceptions). The major question of the materialization of the mind for education has not yet been investigated. The aim of the present study is to explore the possible educational consequences of participation in a neuroimaging protocol on children’s naïve mind–brain conceptions. Although the question of the materialization of the mind has some implications for cognitive development and academic learning [8], studies are still scarce.

The mind–body relation is a great philosophical question that has traveled through the ages. This relation has been studied in children in the particular context of death (for a review, see [9]). It has been observed that two conceptions of death co-exist, a biological one and a metaphysical one. In the biological conception, death is an end-point that implies the cessation of living processes. The mind and the body, which are linked here, stop functioning. In the metaphysical conception, which is shared by numerous religions, death is a transition that marks the beginning of the afterlife. The mind and the body are dissociated. This latter conception seems to be more frequent among adolescents and adults than among younger children [10,11]. In the course of development, we can observe an inclination toward dualistic thinking about the mind compared to the body.

Bartoszek and Bartoszek [12] explored the development of brain conceptions through 5- and 10-year-old children’s drawings. Children were asked to draw what they thought they had inside their brain. An increasing number of typically developing children have participated in neuroimaging protocols by lending their brains to science. This special experience gives them an opportunity to learn about their own brain.

Research Article

When I Met my brain: Participating in a neuroimaging study influences children’s naïve mind–brain conceptions

Sandrine Rossi, Céline Lanœ, Nicolas Poirel, Arlette Pineau, Olivier Houdé, Amélie Lubin

* Université de Caen Basse-Normandie, LaPsyDÉ UMR 8240, Caen, France
** CNRS, UMR 8240, France

E-mail addresses: sandrine.rossi@unicaen.fr (S. Rossi), amelie.lubin@parisdescartes.fr (A. Lubin).

http://dx.doi.org/10.1016/j.tine.2015.07.001
2211-9493/© 2015 Elsevier GmbH. All rights reserved.
their head. The authors found that younger children understood what the brain contained as mental images (e.g., a head contained objects such as a heart, a house, a dog, or the child’s mother’s face) and progressively developed an anatomical representation of the brain (e.g., brain hemispheres and gyri). Other studies investigated children’s understanding of the relation between the brain and identity using the brain’s transplantation paradigm [13,14]. Children were told that someone had taken the brain out of an animal (e.g., a dog) and had put it into a second animal (e.g., a cat). The children were asked whether the behavioral properties or mental content changed as a result (e.g., after the transplantation of a dog’s brain into the head of a cat: “Does it meow or does it bark?”). The researchers observed a transition to a brain-based view of identity from 5-year-olds to 8-year-olds. Older children judged that the new creature (i.e., a cat with a dog’s brain) kept the behavioral properties or mental contents of the new brain (here, for instance, “It barks”). Corriveau et al. [15] pursued this question by also exploring the role of the mind. Children were told stories in which a magical transformation occurred and resulted in a creature with either a mismatch between its mind and its body or a mismatch between its brain and its body (i.e., a magician turns the body of a character “Chris” into the body of a horse and leaves his mind or brain unchanged). Then, questions were asked about the identity of this new creature (i.e., “If you asked him who he was now, would he say ‘I’m Chris’ or ‘I’m a horse?’”). The results indicated that 5-year-old children had a better understanding of the relation between the mind and identity than between the brain and identity. Moreover, this understanding continued to develop between the ages of 5 and 7 years.

To our knowledge, Johnson and Wellman [16, study 2] conducted the only study that has explored children’s naïve mind–brain conceptions. Children between the ages of 6 and 15 years were asked if various cognitive functions (i.e., mental and sensory-motor functions) could be possible first without the mind and then without the brain, or vice versa. They were also asked about the brain and mind ontology. With age, children increasingly involved the brain in sensory-motor functions in addition to mental functions. In contrast, the mind was reserved for mental functions. Concerning the brain and mind ontology, although the youngest children did not differentiate between the functions of the mind and the brain, they thought that they were separate in the head. With age, children increasingly believed that the mind depended on the brain. However, some limitations could be noted. Johnson and Wellman [16, study 2] investigated various functions through closed questions such as “Suppose you did not have a brain (or mind); could you still think (for instance)?” The authors did not spontaneously interrogate the children about what humans need to perform these functions. From a methodological point of view, their focus on the mind and brain during questioning without distractors such as eyes or a mouth, for instance, could influence the children’s responses. Marshall and Comalli [17] replicated Johnson and Wellman’s results in a contemporary sample with the same design protocol focused on the conceptualization of only the brain. Notably, they also proposed two questions concerning the nature of the mind–brain relation, but unfortunately, they did not report the obtained results in their paper (p. 9). To our knowledge, no study has focused on these relations by giving children the opportunity to associate (or not associate) the mind and the brain to observe whether children can materialize the mind into the brain.

One way for children to obtain information about brain anatomy and functioning (topics that are rarely taught in elementary school curricula) [17] is to participate in a neuroimaging study. In one of our magnetic resonance imaging (MRI) protocols with typically developing young children [18], parents and teachers anecdotaly reported that their children were very proud to participate, more motivated in school, less introverted, and more interested in science. This unique experience seemed to have an important effect on the children, who learned many things about their brain. Consequently, participating in this neuroimaging protocol might have consequences on children’s naïve mind–brain conceptions. Do children materialize the mind into the brain more as a result of this scientific experience?

To explore children’s naïve mind–brain conceptions, we developed the Mind–Brain Questionnaire (MBQ). All children were presented with a character designed in different contexts in which cognitive functions occurred (“see” and “talk” as basic functions, “read” and “count” as scholastic functions, and “dream” and “imagine” as mental functions). The children had to indicate from the brain, mind, eyes, mouth, ears, and heart response cards, which one(s) was (were) necessary for the character to perform in each context. Thus, we could assess whether each child considered the mind and/or the brain useful to the character, and we could observe whether the child materialized the mind into the brain for each cognitive function by choosing the mind and brain response cards together. The experimental group was composed of 8-year-old typically developing children who voluntarily participated in an MRI experiment [18]. After the anatomical session, each child could see her/his brain image on a computer outside the Faraday cage. The neuroradiologist used appropriate software to display the child’s brain and provided a brief explanation of the anatomical structure and answered all questions from the child and her/his parents. This process lasted less than 10 min before the functional MRI session. A control group of children who had never participated in an MRI experiment was matched in terms of age, sex, and education level. We reasoned that if participating in a neuroimaging study influenced children’s naïve mind–brain conceptions, then the MRI group should associate the mind and brain together more frequently than the control group. Because we know that the mind is often reserved for mental functions and that the brain becomes more frequently involved in sensory-motor functions with age [16], we hypothesized differences according to cognitive functions. For instance, the MRI group would give mind and brain responses more often than the control group for all cognitive functions but particularly for the basic functions. On the contrary, if participation in a neuroimaging protocol did not influence children’s naïve mind–brain conceptions, no group effect should be expected.

2. Method

2.1. Participants

Seventy-four typically developing children were recruited from schools in Caen (Calvados, France). Half of them (n=37, 8 ± 0.6 years, 23 girls) participated in a MRI protocol on the Cerceron biomedical imaging platform (www.cyceron.fr) [18]. Control children (n=37, 8 ± 0.6 years, 23 girls) were matched in terms of age, sex and education level with the MRI children group. The two groups did not differ significantly in age, sex or education level (all ps > .05). All participants were from middle-class homes, and all spoke native French. Written consent was obtained from the parents and the children themselves after detailed discussion and explanations were given. The children were tested in accordance with national and international norms that govern the use of human research participants.

2.2. Material and procedure

The experiment took place individually at the elementary school of each child. All children completed the MBQ, which was
specifically constructed to assess naïve mind–brain conceptions in typically developing children. A drawing with a character (Julie) and her cats was presented to each child (Fig. 1A). The experimenter explained that Julie performed certain actions with her cats (see, talk, read, count, dream and imagine). Then, the response cards (brain, mind, hand, eye, mouth, and heart) were presented, and the experimenter ensured that the child recognized all response cards (see Fig. 1B). After familiarizing the child with the material, the experimenter asked the child, “What does Julie need to do this action (e.g., see her cats)?” The experimenter indicated that there was no right or wrong answer, that many answers were possible and that he was only interested in what the child thought. Then, the child could choose one or more response cards that were randomized on the table to answer the question. The procedure was repeated for each of the six functions (basic functions “see” and “talk”, scholastic functions “read” and “count”, and mental functions “dream” and “imagine”) presented in random order (Fig. 2). Each child in the MRI group and his/her control match performed the same order presentation. Importantly, the experimenter had never met the MRI children before. Consequently, these children could not make a connection between their past participation in the MRI protocol (which took place 2 years earlier) and the present study.

2.3. Data analysis

Because our objective was to explore children’s naïve mind–brain conceptions, we retained the mind and the brain response cards for the analysis. The other response cards were considered distractors (hand, eye, mouth, and heart). In the MBQ, a child can choose for each separate function (see, talk, read, count, dream and imagine) (1) the mind and brain response cards, (2) the mind response card (without brain), (3) the brain response card (without mind) or (4) neither the mind nor the brain response card. These constitute four response categories. Then, for each function, the child received 1 to indicate her/his response category and 0 in the other three response categories. Each child appeared in only one of the four response categories, which were exclusive. Subsequently, separate functions were paired in basic functions (see and talk), scholastic functions (read and count), and mental functions (dream and imagine) to constitute the 3 function types. Each child received a score from 0 to 2 for each function type. We analyzed these scores nonparametrically with a multinomial logistic regression model, a special case of generalized linear model and thus analogous to linear regression [19]. We used group as the between factor (MRI or control group) and function as the within factor (basic, scholastic, or mental). In the absence of significant interaction, we performed planned comparisons to evaluate the group effect. We ran a complementary analysis on the distractor responses as a measure of baseline knowledge, which should be similar in the two groups. We analyzed the group effect on response frequencies for each separate function (see, talk, read, count, dream and imagine) with a Chi-square test.

Fig. 1. (A) Julie, the main character, with her cats. (B) For each cognitive function, children have to choose one or more response cards that display a hand, eye, mind, mouth, brain, or heart to answer the question “What does Julie need to perform this action (e.g., see her cats)?”.

Fig. 2. The main character presented to illustrate six functions that are basic functions (seeing and talking), scholastic functions (reading and counting), and mental functions (dreaming and imagining).
3. Results

3.1. Mind and brain response category

The MRI group gave significantly more ‘mind and brain’ responses than the control group did (Wald $\chi^2 (2)=6.7, p=.03$). We also found a significant effect of function ($\chi^2 (4)=47.4, p<.001$). Children more frequently chose mind and brain together for mental functions (dreaming and imagining) than for the other functions (all $p<.001$). The interaction was not significant (Wald $\chi^2 (4)=0.23, p>.05$). As shown in Fig. 3A, the group effect was more important for mental functions ($\chi^2 (2)=5.9, p=.05$), whereas no group effect was found for the basic and the scholastic functions ($p>.05$).

3.2. Mind-without-brain response category

The MRI group gave fewer mind-without-brain responses than the control group did (Wald $\chi^2 (2)=7.2, p=.03$). We found a significant effect of function ($\chi^2 (4)=61.5, p<.001$). Children more frequently chose mind-without-brain responses for mental functions than for the other functions (all $p<.001$). The interaction was not significant (Wald $\chi^2 (4)=1.5, p>.05$). As shown in Fig. 3B, the MRI group gave significantly fewer ‘mind without brain’ responses than the control group for the mental functions ($\chi^2 (2)=7.9, p=.02$), whereas there was no group effect for the other functions (all $p>.05$).

3.3. Brain-without-mind response category

We did not observe a significant effect of group (Wald $\chi^2 (2)=0.05, p>.05$). We found a significant effect of function ($\chi^2 (4)=25.7, p<.001$; Fig. 3C). Children more frequently chose the ‘brain without mind’ responses for scholastic functions than for basic functions and mental functions and for basic functions than for mental functions (all $p<.005$). The interaction was not significant (Wald $\chi^2 (4)=1.5, p>.05$).

3.4. Neither mind nor brain response category

We observed a significant effect of group (Wald $\chi^2 (2)=10.8, p<.005$) on the ‘neither mind nor brain’ response. This response was given less frequently by the MRI group than by the control group. We also found an effect of function (Wald $\chi^2 (4)=105.9, p<.001$). This response category appeared more frequently for basic functions than for the other functions and more frequently for scholastic functions than for mental functions (all $p<.001$). The interaction between group and function was not significant (Wald $\chi^2 (4)=1.8, p>.05$). As shown in Fig. 3D, the group effect was more important for basic functions (Wald $\chi^2 (2)=6.2, p=.05$) and scholastic functions (Wald $\chi^2 (2)=6.5, p=.05$), whereas no group effect was found for mental functions ($p>.05$).

3.5. Distractor responses as a measure of baseline knowledge

We separately performed an analysis of the distractors as a measure of baseline knowledge. As expected, the MRI group and the control group did not differ according their choice of the distractor response cards. We observed that children chose the eye for seeing ($\chi^2 (1)=0.15, p>.05$), the mouth for talking ($\chi^2 (1)=3.6, p>.05$), the eye and the mouth for reading ($\chi^2 (0)=0.8, p>.05$), and the eye, the mouth and the hand for counting ($\chi^2 (1)=0.03, p>.05$). Furthermore, we observed that the children did not choose distractors for the mental functions (dream and imagine). Thus, both groups had the same knowledge concerning the role of the distractors in the different functions.

---

**Fig. 3.** Percentages of children in each response category according to the Group and the Function. (A) Mind-and-Brain response category. (B) Mind-without-Brain response category. (C) Brain-without-Mind response category. (D) Never Mind nor Brain response category. *p < .05, ns = non-significant.
4. Discussion

Our study revealed an educational effect of participation in a MRI protocol on 8-year-old children’s naïve mind–brain conceptions. Children seemed to have a better understanding of the relation between mind and brain, particularly for mental functions such as dreaming and imagining. They materialized the mind into the brain. This relation was less clear for basic (seeing and talking) and scholastic (reading and counting) functions. In contrast to the control group, the MRI group rarely gave mind-without-brain responses, and the difference between the groups appeared more specifically in the mental functions. Indeed, although a majority of children in the MRI group answered that the mind and brain were simultaneously necessary for dreaming and imagining, the control group more frequently gave mind-without-brain responses, suggesting that the control group had more difficulty materializing the mind into the brain. All of these results are supported by the absence of difference between the two groups of children on their distractor responses, which emphasized the effect of participation in a neuroimaging protocol on the understanding of the importance of the mind–brain relation.

Contrary to Johnson and Wellman’s study [16], which observed that 8-year-old children judged the mind and the brain as equally important for mental functions, our MBQ revealed that this was not so obvious for the children in our control group. Corriveau et al. [15] observed in natural language that parents use the term mind more frequently than the term brain when they talk to their children about mental functions. In that case, parents certainly impart some misconceptions. In addition, for both groups, the mind-without-brain response category occurred very rarely in basic and scholastic functions, which suggests that the mind alone is not useful for all children. However, the brain also seemed crucial for learning activities such as reading and counting in both groups, although it appeared to be more important for the MRI group. Finally, the children in our MRI group believed less often than the control group that neither the mind nor the brain is useful for performing basic and scholastic functions, which suggests that these children consider the brain to be more useful for all cognitive functions, even if it is not always associated with the mind.

Our MBQ seems to provide an effective method for evaluating naïve mind–brain conceptions because it not only focuses children on their mind or brain but also gives them the opportunity to choose it from among distractors (hand, eye, mouth, and heart). These distractors are, of course, useful for performing functions (e.g., the eyes are necessary to see), but not alone. Our method allows for the observation of whether children spontaneously provide a role for the mind and brain in the performed function. The children’s responses were less influenced, which is most likely the reason why our control group results differed from those of Johnson and Wellman [16]. Because of this new questionnaire, we are able to better understand the intertwined relation between the mind and the brain in childhood.

To add arguments in favor of the educational effect of an MRI protocol, it is important to emphasize that our study was conducted without making a connection with the previous MRI experiment. Moreover, during the MRI experiment, we did not address the role of the mind and the brain with the children. Nevertheless, two years after their participation in this particular experience, the children presented different mind–brain conceptions. What can be assumed about the mechanism of children’s understanding of the role of these entities in bodily functions? The children saw their own brains, which allowed us to shape the link between their own mental states and their brain. This provides an opportunity to enter reflexive self-consciousness and to see the ‘black box’ differently. For children, this special meeting, which was emotionally loaded, could emphasize the role of the mind and the brain in human functioning. One could argue that the present study lacks a pre/post methodology. This is indeed a major limitation in our design. We received positive feedback from parents and teachers about the beneficial impact of our MRI protocol on children, particularly about their awareness of brain activity in daily life. We decided to conduct an experiment to measure this benefit. Nevertheless, further work will be required to confirm this beneficial effect by using a pre/post methodology and testing it over time.

A better understanding of the development of children’s naïve mind–brain conceptions would be useful to find ways to add new knowledge to what children already possess [12]. The study of the brain is rarely integrated in school curricula [17] and presents important variations according to countries. In France, for instance, the study of the brain is not in the curriculum, although some independent programs emerge in schools (e.g., La main à la pate, http://www.fondation-lamap.org/fr/ceveau, for elementary schools and Neurosup, http://www.neurosup.fr/, for secondary schools). Only students in science curricula are concerned with the study of the brain, but these studies occur at the end of high school. Given that the majority of children receive no formal instruction about the brain’s anatomy or functioning, they struggle to construct an appropriate mental representation [20]. Children learn information about the brain through testimony [21] and often informally. The mind is included more often in reference to mental functions, whereas the brain is confined to cognition [15]. Developing neuroscience programs in schools may be useful to remediate to this misconception [17,22], modify implicit theories of intelligence, and improve motivation and academic learning in adolescents [23,24].

5. Conclusion

The present study is the first to show an educational effect of participating in an MRI protocol on children’s naïve mind–brain conceptions. Children benefit from new knowledge they acquire from the MRI protocol. In the past few years, there has been growing interest in the field of neuroeducation, which aims to bridge the gap between developmental cognitive neuroscience and education. These studies investigate the neural mechanisms of learning and offer new information about the brain that is useful for educators [25,26], and a large majority of educators find relevant neuroscience for practice [24]. However, despite this enthusiasm, the relation among neuroscience, cognitive psychology and education remains difficult, and their transfer into the classroom remains rare [6]. Given that the brain is the organ of learning, it seems important to inform educators about how brains learn [8,27]. In this context, neuroimaging studies could offer a complementary brain education program that could be implemented in a pedagogical project to encourage opportunities for teaching developmental cognitive neuroscience in early elementary classrooms [8,28].

Acknowledgments

We wish to thank Medhi Contrel for his valuable help with the conception of the material and the data collection. We also would like to thank the School Inspectorate of Calvados and the teachers, the children and their parents for participating. We also sincerely thank the reviewers for providing constructive comments on an early version of this manuscript.
References


