https://doi.org/10.17163/soph.n33.2022.05

What happens inside my head when I think?

¿Qué pasa dentro de mi cabeza cuando pienso?

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Suggested citation: Oliveira-Martins, Taís, Eichler, Marcelo Leandro & Vieira, Janine (2022). What happens inside my head when I think? *Sophia, colección de Filosofía de la Educación, 33*, pp. 137-160.

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Abstract

The images about the brain have been gained prominence in the 21st century. In this work, we seek to recognize the representations of children about the functioning of thought, ideas involving mind and brain. This study replicates the Piagetian tradition research conducted with the following guiding question: 'What happens inside my head when am I thinking?' The data were collected through interviews and mainly from the drawings made by the children to represent their beliefs. A total of 51 children from four to twelve years old, from public and private schools from the state of Rio Grande do Sul, Brazil, took part in the study. The collected data were discussed with the original research and intended to understand children's thinking in their representations about the functioning of the mind and brain. It was possible to identify that child associate the functioning of thought with family contexts, typical contents, and key ideas that demonstrate their personal beliefs. The references used in the child representations - for Genevese or Brazilian children - point to feelings, blood flow, mental image, lamps, gears, straps, briefcases, memory, and others. The results found with Brazilian children are very similar to the original research, even though the time gap between polls is considerable. In all ages, the typical content classified as biological was the most indicated by the children.

Keywords

Brain, children, drawing, learning, mind, thinking.

Resumen

Las imágenes sobre el cerebro han ganado protagonismo en el siglo XXI. En este trabajo, se busca reconocer las representaciones de los niños sobre el funcionamiento del pensamiento, ideas que involucran mente y cerebro. Este estudio replica la investigación de la tradición piagetiana realizada con la siguiente pregunta orientadora: '¿Qué pasa dentro de mi cabeza cuando estoy pensando?' Los datos fueron recolectados a través de entrevistas y principalmente a partir de los dibujos realizados por los niños para representar sus creencias. Participaron en el estudio un total de 51 niños de cuatro a doce años, de escuelas públicas y privadas del estado de Rio Grande do Sul, Brasil. Los datos recopilados se analizaron con la investigación original y tenían como objetivo comprender el pensamiento de los niños en sus representaciones sobre el funcionamiento de la mente y el cerebro. Se pudo identificar que el niño asocia el funcionamiento del pensamiento con contextos familiares, contenidos típicos e ideas clave que demuestran sus creencias personales. Las referencias utilizadas en las representaciones infantiles, para niños ginebrinos o brasileños, apuntan a sentimientos, flujo sanguíneo, imagen mental, lámparas, engranajes, correas, maletines, memoria y otros. Los resultados encontrados con niños brasileños son muy similares a la investigación original, aunque la brecha de tiempo entre las encuestas es considerable. En todas las edades, el contenido típico clasificado como biológico fue el más indicado por los niños.

Palabras claves

Cerebro, niños, dibujo, aprendiendo, mente, pensamiento,

Introduction

We currently live in a time of enchantment with neurosciences and theories of mind. After the Decade of the Brain (1990s), studies in neuroscience multiplied, mainly with research aimed at generating and analyzing brain images. For Lisboa and Zorzanelli (2014), the representations of the human brain in contemporaneity have led to a "rise of the brain as a

ISSN impreso:1390-3861 / ISSN electrónico: 1390-8626, pp. 137-160.

privileged, if not exclusive, place of origin of the mind, behaviors, choices and desires" (p. 364).

In this sense, it is not surprising that the theme of neuroscience is found in museographic exhibitions. Molinatti and Girault (2007) carried out an analysis of four museum exhibitions on the brain held at the turn of the millennium. The analysis was carried out from a socio-constructivist didactic perspective that paid particular attention to the study of the visitors' conceptions, extended to their social practices of reference. With regard to the scientific knowledge presented in the exhibitions and retained by the visitors, the investigation identified that it is essentially a reductionist and monistic neuropsychological perspective, of the concepts of neuroplasticity and the interaction between the genome and environmental factors in the realization of the phenotype brain. In their conclusions, the authors point out the difficulties of museological institutions in explaining the history of the relationship between the brain sciences and society. In this sense, the museological popularization of neurosciences seems to proceed more from an update of basic scientific knowledge, in light of recent studies on brain imaging, than to present and reflect the possible theoretical and methodological debates and the necessary scientific controversies in the specialized community.

Despite the variety of materials and research methods, research in neurosciences tends to look at the mysteries of the brain and its functioning. For this, initially, it is opportune to pay attention to the warning by Fuentes and Collado (2019), who warn that the orientation of educational and school decisions based on 'neuroscientific evidences' should not be conceived as a 'panacea' or as the only support and foundation for a 'new educational revolution'. This type of approach would be characterized by a 'naïve' enthusiasm, based on non-systematized approaches and without the necessary rigor. Furthermore, this biased approach would have been responsible for the emergence of an authentic neuromythology in the field of education, which could be named as the paradigm of Brain-Based Learning.

In relation to the philosophy of mind, several authors consider Jerry Fodor's thesis (1935 - 2017) indispensable to raise a philosophical discussion about mental states, intelligence and the role of computational models in cognitive processes. Particularly, in this sense, his modular-computational theory is recognized as an indisputable contribution to the current models of the philosophy of mind.

The criticism of Fodor can be found in recent articles published in this journal. Tillería (2021) undertakes the critique of Fodor's com-

ISSN impreso:1390-3861 / ISSN electrónico: 1390-8626, pp. 137-160.

putational theory of mind, which seems to have an undeniable contribution to current models of cognitive science, in particular considering his idea of informational encapsulation. In turn, Bernache (2021) develops a critique of the notion of internal representation, which would have a primary function to explain cognitive activity.

However, following the suggestions of Mounoud (1996 and 1997) and Richelle (2000), in this article we intend to show how Jean Piaget's (1896 - 1980) approach to the mind and cognitive development can be productive in going beyond naive, albeit paradoxically, highly literate and influential elaborations.

Mounoud (1996 and 1997) indicated that most of the references in the debates about the new reductionist theses proposed by the philosophers of the mind (including the psychological approaches about the 'theory of mind') gave the impression of studying a new area of research, with new and unexplored problems. However, the author suggests that it is surprising to note the complete absence of references to Piaget in the works of all these philosophers (including Fodor), since the contribution of the Swiss epistemologist is considered one of the most comprehensive of the 20th century.

As Richelle (2000) emphasizes, the omission of Piaget's work is almost general, despite Piaget's work being one of the most fertile in twentieth-century psychology, including in the approach to the old theme of the mind and its relations with the body:

> Piaget's anchoring in biological thought would have justified the attention, however allusive, of the numerous authors who participated in the debate on brain and mind, although the Genevan epistemologist was little interested in the spectacular advances in neurosciences initiated at the end of his career [But] (...) this does not in any way diminish the relevance of his works for those who wonder about the nature of the mind and its relations with the brain (...) Is Piaget already forgotten, (...) knowing that, whether about consciousness or about the mind, just a few pages of his work teach us more than many volumes born out of a recent fashion? (Richelle, 2000, p. 233 - 234, our translation).

Therefore, this article is also a tribute to Jean Piaget's immense contribution - the text was written on the occasion of the celebration of the 40th anniversary of his death - to the understanding of the development and acquisition of human knowledge. Swiss Jean Piaget was primarily a naturalistic biologist. Influenced by evolutionary works and nature studies, he adopted the scientific method as a working system. His curiosity about how things and minds work led him to use naturalist search methods for all his later research, and to formulate the theory of Genetic Epistemology, the work of a psychologist interested in how the

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human mind develops, and how knowledge is acquired. Montangero and Maurice-Naville (1998) stated, about Piaget, that:

> […] he produced the most complete theory of intellectual development because it deals with the period from cradle to adulthood and strives to define the links of intelligence and logic with other cognitive functions such as memory, language, perception, etc (p. 17; our translation from Portuguese version).

Before that, still, at the beginning of the 20th century, Piaget researched how human beings build their knowledge about the world from research with children. These researches revolutionized psychology's beliefs about epistemology. Jou and Sperb (1999) refer in their work to a large number of researchers who claim that Piaget was the first "to take an interest in children's mental contents and the processes responsible for these contents" (p. 288). These researches started at preschool ages and extended to follow the evolution of children's thinking.

Therefore, the study presented here sought to follow what children believe happens in our heads when we think. When carrying out this mapping, important questions arise. The first is how children of different age groups see the functioning of thought, its importance, and its mechanisms. The second is about the maturation of children's representations, their delay or absences, can also be discussed. Is it possible to perceive by the representations of children, through drawing, how they perceive the functioning of the mind and brain?

It's known that Piaget dedicated his research to understanding how human beings build their knowledge. He demonstrates that the subject-object interaction also occurs with biological meaning, and learning is nothing more than the organism's adaptation to the environment in which it's inserted. Furthermore, it's also known that the roles of mind and brain are complementary and interdependent, although different.

From tests and clinical interviews that began at preschool ages and extended to follow the evolution of children's thinking, Piagetian research revolutionized psychology's beliefs about epistemology. In his work *The representation of the world in children*, originally from 1926, Piaget presented a long-term study on the reality and causality present in children's thinking. This study is part of the 1st period of his works (the 20s to early 30s), whose themes were called at understanding children's mentality and the progressive socialization of thought, seeking the specific nature of young children's thinking and the differentiation of this thinking that of the adult (Montangero and Maurice-Noville, 1998).

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This book related more than 600 observations in many settings, and then, to present the description of the development of children's thinking about their spontaneous representations of the world, moving from realism to animism and finally to artificiality. Analyzing and understanding the form, functioning, and content of children's thinking proved to be a complex task, as according to Piaget (2005):

> […] the form and functioning of thought find out each time the child comes into contact with other children or with the adult: it is a form of social behavior that can be noted from the outside. The content, on the contrary, shows itself or not, depending on the child and the objects of representation (p. 10; our translation from Portuguese version).

In addition to Piaget's studies, other researchers such as Carey, Zaitchik, and Bascandziev (2015) reaffirm and expand the discussions proposed by Piaget for children's representations when they present the concept of 'vitalist biology' as a "theory spread across different cultures that highlights thinking about life, death, health" (p. 3). According to these authors:

> Vitalism provides a functional understanding of bodily processes: the body functions, bodily organs, and bodily processes to sustain life, health, and growth. [...] The process of building vitalistic biology starts young at the age of 4 or 5 years old for some children, with an average age for the emergence of some fundamental principles around 6 or 7 years (Carey, Zaitchik and Bascandziev, 2015, p. 4).

In the field of neurosciences, the stages of human development established by Piaget in the 3rd period of his work (between the late 1930s and the late 1950s), in which the subject of study was focused on the formalization of mental structures to explain the organizing and explanatory power of reasoning in addition to providing explanations for the qualitative leaps in the course of cognitive development (Montangero and Maurice-Noville, 1998), were confirmed years later by the extensive research by Epstein (1974a and 1974b), which established the correlation between brain development and Piaget's stages of thought development, and which was later endorsed by Hudspeth and Pribram (1990), Hansen and Monk (2002), among others.

Representations of the mind and brain in children

The mental contents studied by Piaget also are addressed in the area of psychology called theories of mind (Mounoud, 1996 e 1997; Richelle, 2000). Jou and Sperb (1999) defined this theory as an area of investigation into "the

ISSN impreso:1390-3861 / ISSN electrónico: 1390-8626, pp. 137-160.

ability of preschool children to understand their mental states and others, in this way, predict their actions or behavior". The interest of researchers in theories of mind is focused on the first manifestations of understanding it and the possibility of representing it. It is possible to identify the beginning of these representations around 4 or 5 years old (Saada et al., 1996).

Otherwise, the work of Wellmann (2017) shows that "theory-of-mind understandings begin in infancy, but also progress" (p.2) throughout life. In his report the author states that in the 80s, theories of mind researches were focused "on preschoolers, but now chart theory-of-mind achievements from infancy through adulthood, from nursery to the schoolyard to the classroom and into the highways and byways of social life" (p. 6). Still, it highlights that the child's understanding of the mind and people has an important development around the ages of 5 or 6, and only after preschool years "do children develop a deepening appreciation of the mind as different from the brain" (p. 5).

Mounoud (1996) talks about the child's capacity to attribute beliefs to others. Wellmann (2017) indicates the capacity to attribute beliefs and desires to others. Directly related to Piagetian theory, these researchers point to rational, non-vague, and precise concepts evidenced in young children demonstrating the relation with operations, points of view, egocentrism, and decentration to create ideas about Theory of mind. For Mounoud (1996), the "objective remains to understand the origin of the rational norms or of the laws of the mind" (p. 100).

In a study on children's notion of thinking, Piaget (2005) identified three stages (or levels) of child realism development and, on the importance of these notions, stated that the "awareness that we have to think distinguishes us, in effect, from things" (p. 37), noting that children ignore the specifics of thought, "even at the stage where they are influenced by what adults say about the 'spirit' the 'brain' the 'intelligence'"(p.37). In his description of these stages, it was observed that in the first stage:

> […] children believe that we think 'with our mouth'. Thought is identical to voice, and nothing happens in the head or the body. Of course, thought is confused with things themselves, in the way that words are part of things. There is nothing subjective about the act of thinking. [...] The second stage is marked by adult intervention. The child learned that one thinks with the head, sometimes even mentioning the 'brain' [...] Indeed, thought is often conceived as a voice in the head, or in the neck, which indicates the persistence of the influence of the child's previous beliefs. Finally, it is the materiality that the child attributes to thought: it's made of air or blood, or it is a ball, etc. The third stage, whose average

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> age is 11-12 years, marks the dematerialization of thought (Piaget, 2005, p. 38-39; our translation from Portuguese version).

Also in this same study, it was pointed out that although some 9-year-old children have this characteristic, the average age is 11 years old so that they start to manifest that "thought is not a matter and differs from the phenomena it represents" (Piaget, 2005, p. 51). Before this, it is characteristic that children present two confusions according to Piaget:

> [...] between thinking and the body: thinking is for the child actors of the organism – the voice. It is, therefore, one thing among things, consisting essentially in acting materially on the objects or people that are of interest to us. But there is, on the other hand, the confusion between signifier and meaning, between thought and the thing thought. From this point of view, the child doesn't distinguish, for example, a real house and the concept, the mental image, or the name of that house (Piaget, 2005, p. 51; our translation from Portuguese version).

In the work presented by Carey, Zaitchik, and Bascandziev (2015), it was pointed out that the 'intuitive biology' of children, studied by Piaget (2005) as animism (when children tend to indicate the existence of life based on the presence of movement or utility of beings and objects), undergoes conceptual changes over time. According to them when young children:

> [...] are asked about the functions of Organs bodily organs, they tend to report a single and independent function for each part of the body (e.g., the heart is for beating), demonstrating a lack of understanding of the body as a biological system whose the parts work together to sustain life.

When this 'intuitive biology' is in action, somewhere between 5 and 12 years old, according to Carey, Zaitchik, and Bascandziev (2015), many advances in children's thinking are observed, especially that:

> [...] the concepts of living, real, present, and existing are differentiated; the plant and animal categories have adhered to a single category of *living organisms*; the mortal is distinguished from *inanimate*, and self-propelled movement and activity are no longer at the heart of the concept of alive. (p. 14)

Regarding the representations made by the children, they are accessed and studied through drawing by several authors. Einarsdottir, Dockett, and Perry (2009) carried out a study on the analysis of children's perspectives through drawing and highlighted that this type of approach shows the fluidity and flexibility of the child's construction of meaning, in addition to reflecting their control of the process.

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In this sense, it is important to rescue Reith's (1997) description that many fields of study and practice of psychology focus on the perception and production of graphic representations (not only images - such as drawings, paintings and photographs - but also representational systems such as maps, plans, diagrams, graphs, etc). In this sense, one can distinguish two categories of work in psychology that are interested in graphic representation. The first includes works that use graphical representations as a means of exploring the mental life of individuals or as a methodological instrument to carry out basic research on psychological processes. The second category consists of works in which the pictorial presentation is an object of study in itself. The researcher seeks to obtain information on the subject's knowledge of drawings and graphics, on the processes involved in their perception and production, as well as on the paths taken by the subject in acquiring the capacity to implement them.

If we were to follow such criteria, we would have to indicate the hybrid character of our research approach, like other authors, such as Giordan and Vecchi (1996), who aimed to study students' conceptions about the human body and the evolution of this knowledge in the school environment, and Rabello (1994) who also carried out a study using representation to analyze perceptions about the human body in children, refer to several other authors who use the same technique. Through these works, it's possible to identify how children, and even young people, represent their bodies it's much more linked to the imagination than to reality. The lapses, that occurred in the formation of school concepts about the body itself are quite visible in these representations. The central nervous system (CNS) and its functioning were not addressed in the works mentioned above, even with important relevance for the body as a whole. Understanding children's representations about the brain, thinking, and its functioning helps us, above all, to understand how this theme can be initially approached in their study.

In the research by Molinatti and Girault (2007), on museum exhibitions about the brain, the conceptions of children and adolescents about the brain were inventoried. The study showed that for older children, the brain is involved in 'intellectual' situations (talking, counting, etc.). The brain learns, commands and controls, but it is also very rarely involved with emotions, for example with love. Children ask themselves about the composition of their brains and use analogies with the intestines (speaking of "the bowels of the head") or with the brain-computer model (evoking the entanglement of wires, the existence of a memory, of a "central unit"). In teenagers, however, the limits of school culture can be seen, since many notions such as neurons and nervous messages are not accommodated by

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most teenagers, despite a lexical varnish. Teenagers often use the model of the 'muscle brain' that commands, that acts. Furthermore, a constant in mapping teenagers' conceptions to the brain is the famous "we only use 10% of our brains", albeit without any scientific basis. Finally, there were frequent references to brain pathologies and disorders.

A clear example of how the children's representation of thought was used, in a very interesting way, occurred during the Jean Piaget centenary celebrations. On this occasion, a congress occurred in Geneva with the theme 'Thought in evolution'. Among the activities of this congress, there was a large exhibition, which had a part dedicated to children's works. In preparation for this event, an academic group, from all levels, was selected to study, classify and sort thousands of documents from the Jean Piaget Archives and the Archives of the Jean-Jacques Rousseau Institute. Subsequently, this work resulted in a fixed exhibition at the Museum of Ethnography in Geneva (between September 1996 and January 1997), followed by a traveling exhibition that visited all the continents. This exposition is reported in the book whose title can be translated as: *Jean Piaget: acting and building, the origins of knowledge in children and students* (Hameline and Vonèche, 1996).

The third chapter of this book has the theme used in this research: 'Qu'est-cequi se passe dans ma tête quand je pense?' (Saada *et al.*, 1996). At the time, the researchers interviewed about 500 children from 4 to 12 years old, students from Genevean schools. To these, it was proposed that they represent, in the form of drawings, models, decoupage, among others, what they believed to be the answer to the question: 'What happens in my head when I think?'. The original research was aimed at demonstrating that fundamental beliefs about the nature of thought and its participation in human action are decisive for the social and cognitive development of children. The authors of the research believe that the metarepresentations of children on this topic, the reflection on their thinking and that of others, exert an important influence on cognitive and social development – acquisition of spoken and written language, moral judgment, memory, social interaction, and more.

For over two decades later, this study then proposed to question children again, using the technique of child representations through drawing.

Methodology

Using Jean Piaget's clinical method, an open conversation was proposed with the child, seeking to follow their ideas and explanations on the pro-

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posed topic for data collection through interviews. Delval (2002) describes that the Piagetian clinical method aims to "investigate how children think, perceive, act and feel" (p. 67).

According to Delval (2002), the clinical method was named by psychologist Lightner Witmer in 1896. Initially created to prevent and treat mental deficiencies and anomalies, it was used together with other tests to reach a diagnosis. Afterward, it came to be used by psychiatrists for a detailed study of individuals, allowing generalizations and the establishment of categories of symptoms and diseases. Starting in 1919, Piaget, carrying out a study commissioned by Theodore Simon on the standardization of intelligence tests, "initiated a method of open conversations with children to try to capture the course of their thinking" (Delval, 2002, p. 55).

As time went by and his research matured, Piaget reformulated the method that was no longer based purely on conversation and started to use activities carried out by the subject to establish a free dialogue, adapted to each child and helping them to become aware and formulate their mental attitudes. According to Delval (2002), language in the clinical (or critical) method is used to:

> […] give the subject instructions on what to do, to ask him to explain why he is doing it, to give him suggestions about what he is doing, to try to explain what he is doing to find out what difficulties he has, and what is the course of his thinking, but without supposing (as was the case in introspective works) that the subject will explain the course of his thinking, which is an unconscious activity but, rather to, obtain data that allow us to formulate hypotheses about the organization and functioning of his mind (p. 65; our translation from Portuguese version).

In the present study, the interviews were based on the question 'What happens inside my head when I think?'. This question was common to all, but it was expanded and complemented according to the responses of each one. The answers, according to Piaget (2005), guide the course of the interview.

> To evaluate children's logic, it is often enough to argue with them; it is also enough to observe them with each other. Judging your beliefs requires a special method, which we warned from the beginning is difficult, laborious, and requires a point of view that assumes at least a good year or two of training (p. 10; our translation from Portuguese version).

For the preparation of the basic questions of the questionnaire, Piaget (2005) talks about the importance of knowing children's spontaneous questions about the subject and then applying the very form of

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these questions to those that are intended to be asked to the children in the interview. Boschvitsch (1974, *apud* Roazzi, 1987) showed that completely different answers can be obtained depending on the context (formal versus informal) and the interviewers (teacher versus psychologist). As a result, the interviewers' classroom experience was useful to plan questions that could be presented with different approaches according to the age group and without the child feeling the need to respond with the formality and rigor of the classroom, but with spontaneity.

Another concern present in this process was to structure the interviews to avoid 'fabulation' and "suggested belief" as much as possible. Following the criteria set out by Piaget (2005):

> When the child, without further reflection, answers the question by inventing a story in which he does not believe or in which he believes through simple verbal training, we say that there is *fabulation*. When the child tries to answer the question, but the question is suggestive, or the child simply tries to please the interviewer, without resorting to his reflection, we say there is a *suggested belief*. [...] When the child responds with reflection, extracting the response from its base, without suggestion, but the question is new to her, we say that there is a *belief triggered*. The belief triggered is necessarily influenced by the interrogation, since the very way of asking and presenting the question to the child forces him to reason in a certain direction and to systematize his knowledge in a certain way, but it is nevertheless an original product of the child's thinking, for neither the reasoning done by the child to answer the question nor the body of prior knowledge that the child uses to reflect is directly influenced by the experimenter. [...] Finally, when the child doesn't need to reason to answer the question but can give a ready answer, because it has already been formulated, there is a *spontaneous belief*. There is, therefore, spontaneous belief when the question is not new to the child and when the answer results from a previous and original reflection (p. 16; our translation from Portuguese version).

When the children are invited to answer this very original question (what happens inside my head when I think about it?), there was still the concern that there would be an opportunity for reflection. From the initial question, it was proposed that the children make representations of their answers using drawings. Different from the original work, which used the construction of models, decoupage, and others (for representations), in addition to the drawing technique, the present study used as a resource the drawing on a sheet of paper, using colored pencils, crayons, and pens. After completing the task, the interviewer asked the subjects to explain, in words, what they had drawn. From the child's explanations

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and the basic script of questions prepared, the interview was conducted to understand what the child believed was going on in his head while thinking. Thus, it was expected that it would be possible to access the 'unleashed beliefs' of the children interviewed about the proposed theme.

Table 1
Family contexts presented in the chapter
"Qu'est-cequi se passe dans ma tête quand je pense?"

Family Context	Description
Sociological Context	It corresponds to the presentation of a central figure responsible for the global control of the brain, often accompanied or replaced by several characters who share control by transporting and communicating information.
Mechanical Context	It is driven by the movement and flow of energy, through gears, cranes, pulleys, liquid or solid channeling circuits (belt, bearing, etc.)
Computer Context	It suggests a tangle of circuits, often an arrow, that indicates the direction of information flow. It also suggests the expression of a hierarchical control (central frame) or distributed controls (several linked elements), memory (information storage), and information processing (channels through a ball, for example).
Technological Context	It refers to the operation of devices such as audio and video recorders, calculators, cameras, cameras, etc. Children, therefore, show the link between, on the one hand, taking information through thought and retention - memorization, and, on the other hand, the input of information, its production, and its conservation by a man-made device.
Biological Context	That affects the organism, here especially the brain, according to the knowledge that children may have of its functioning, especially concerning neuronal flow and blood flow in circuits, channels, pipes, tangles of variable complexity. The sense organs play the role of entry (often in the ear) and exit (usually in the mouth) of the flow of information.

Source: SAADA *et al.* (1996, Author's translation).

Interviews were carried out with 51 Brazilian children from 4 to 12 years old. As the procedures took place in two schools, we informed the ages of interest for the research, and the pedagogical coordinators of each school selected the participating students without interference from the researchers. All respondents came from a public school and a private school, located in the state of Rio Grande do Sul, and those responsible for the students who participated in the research signed the Informed Consent Form, authorizing the use of the information obtained.

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ISSN impreso:1390-3861 / ISSN electrónico: 1390-8626, pp. 137-160.

The children's representations, along with their explanations, were classified according to the family contexts (Table 1), the typical contents mentioned and the underlying key ideas (Table 2), as described in the original work by Saada *et al.* (1996). From the classification, graphs were generated showing the diversity of responses, in addition to quantifying and comparing the data collected according to age and with the original work.

Table 2
Typical contents and underlying key ideas presented in the chapter "Qu'est-cequi se passe dans ma tête quand je pense?"

Typical Contents	Underlying Key Ideas
- gears, pulleys, straps, transports - electrical network - blood circulation	Circuits
- power plants, engines, batteries, electrical flow	Energy
- central manager character, instrument panel - multiple characters or devices connected - virus (disturbed command)	Control
- input output→ →(e.g., ear mouth)→ - ask answer, calculation, coding - mirror reflection - answer by light: lamps, candles - S.O.S. intelligence box	Information processing
- memory drawers, computer memory, briefcase, image conservation	Memory storage
- mental images: the evocation of events, people, objects... (good grades, my dog, mother) - dreams	Thought-Contents
- pleasure of success - joy, sadness, love, evil, etc.	Emotional states

Source: SAADA *et al* (1996, Author's translation)

Some correlations with this research can be traced from the work of Lisboa and Zorzanelli (2014), where the authors analyze metaphors of the human brain used in scientific popularization materials and reflect on the meanings and associated use with it. As demonstrated by them, a metaphor dominated scientific thought, and other areas (politics, economics, and philosophy), in each era. In this way, the brain has already been described using metaphors such as the hydraulic machine, the clock,

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the steam engine, and, later, the telephone exchange, the computer, and, finally, the Internet.

Mein's (1998) research shows that throughout the History of Science, the answer to questions about the specificity of psychic or mental phenomena and their location - as well as the relationship between these phenomena and our material body - took various forms. The article presents images and descriptions of the cardiocentric or cephalocentric thesis, brain machines (eg hydraulic models, electrical models, the mirror brain, the brain as a computer, the brain as a chemical plant), the brain mosaic and the global brain - in relation to levels of organization and locations. These different ways of conceiving the brain would succeed each other at different times, more precisely, they coexisted without being completely replaced.

On the other hand, the wide diversity of children's representations of the location of thoughts and the functioning of the mind (or brain) suggest the difficulties that are well known in science teaching and, in this particular case, in the teaching of biology (Clément, 1998). These child representations, presented as spontaneous conceptions, are the amalgamation of recollections of cultural learning (which may have taken place in schools or other educational spaces) and of mistakes and factual gaps.

Regarding the theme presented in this article, the research by Bec and Favre (2010), on teaching and learning of the nervous system, shows that the body remains, for most secondary school students, a black box whose structures and modes of functioning are unknown. Most students had great difficulty in acquiring the concepts that were introduced and defined during the teaching sequences dealing with the nervous system in high school classes. Thus, the conceptions appeared in most students as being confused, imprecise, often resulting from empirical analysis and, therefore, not being built from biological data. In their conclusions, these actors indicate that the problem that arises when teaching the nervous system in high school is, therefore, finding an answer to the following questions: why do students have so much difficulty in acquiring the concepts that are defined in the course? Why do they regard the organization as a black box? Why are they so lacking in knowledge of biological structures and their workings?

In the context analyzed here, thus, the representations of children are also related to the social and cultural representations with which they are in contact. According to the authors (Saada *et al*, 1996), children's ideas about the functioning of the mind are represented by the content they have organized according to family contexts, contexts largely related

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to the social representations conveyed in our culture, within and out of school. In this way, the typical contents mentioned could be organized into key ideas that are integrated into family contexts, and these data provided support for the interpretation of the results.

Development

Many may be wary of the results of research carried out in the 1920s or 1930s and use the technological revolution of the last decades to justify the existence of large cognitive differences between those children and those of today, which would invalidate the results of older research. Countless researchers around the world have successfully replicated Piagetian experiments and observed their validity, as in Batistella, da Silva and Gomes (2005). Even with all the ease of access, the high consumption of household appliances, and the widespread use of the Internet, the way children think doesn't seem to have changed. What has changed is the access to information and the speed with which this happens. Jaan Valsiner (2001) highlighted that "technologies advance, information overflows, but children's creative curiosity remains without obstacles imposed by the consumer society" (p. xx).

Children receive early and constant information and notions about their bodies through cartoons, virtual games, magazines for children and in the school environment. However, this study showed that, despite this access to information, the students represented in their drawings similar images to those of the Geneva students in the original study.

Children's ideas about how the mind works are represented by the content they have organized according to family contexts (Table 1). These contexts are largely related to the social representations conveyed in our culture, inside and outside the school. In the original and the current research, sociological, mechanical, computer, technological and biological contexts were considered. All family contexts that were reported in the work by Saada et al. (1996) also appeared in the current research.

The biological family context was most frequently reported at all ages (Graph 1). The reports referring to the organism, here especially the brain, were classified as biological family context, according to the knowledge that children may have of its functioning.

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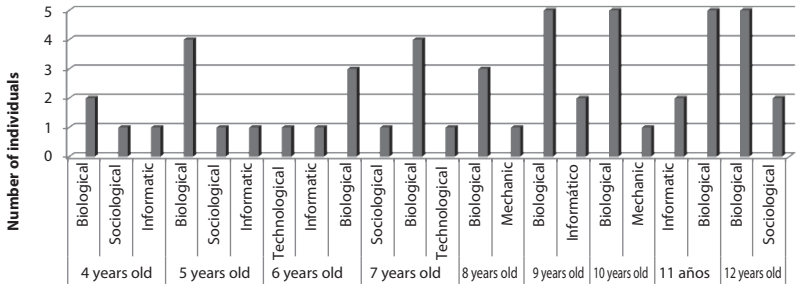
Graph 1
Family contexts identified in the representations presented by age



Source: Produced by the authors.

During the interviews, most children used the word 'brain' in their explanations. Was identified this expression was even among 4 years old respondents (Fig. 1). One of the 6 years old children stood out, using words such as the brainstem, encephalon, and cerebellum (Fig. 2). When questioned, he declared that he learned the nomenclature at school during the presentation of his colleagues. This report highlights the influence of schooling, and especially of, adults, on children's impressions of the functioning of thought.

The family context that was reported less frequently was the mechanic. In this context, representations and speeches that referred to the movement and flow of energy, through gears, cranes, pulleys, liquid or solid channeling circuits (belt, bearing, etc.) were considered. The mechanical context was reported by two interviewees, one eight years old and the other ten years old. The eight-year-old student drew gears and said that when the teacher passes on a content she already knows, these gears move faster and when she doesn't know the content yet, the gears move slower (Fig. 3).

Figure 2
Representation of
a 4-year-old student

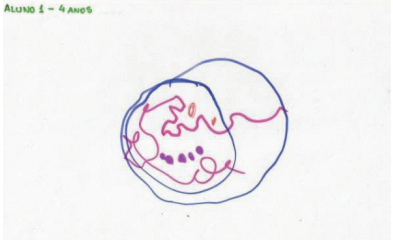


Figure 3
Representation of
a 6-year-old student

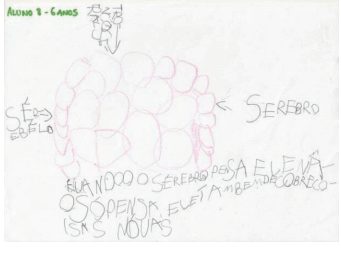


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Figure 4
Representation of
an 8-year-old student

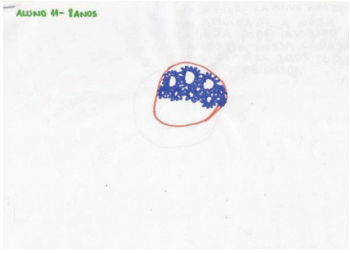
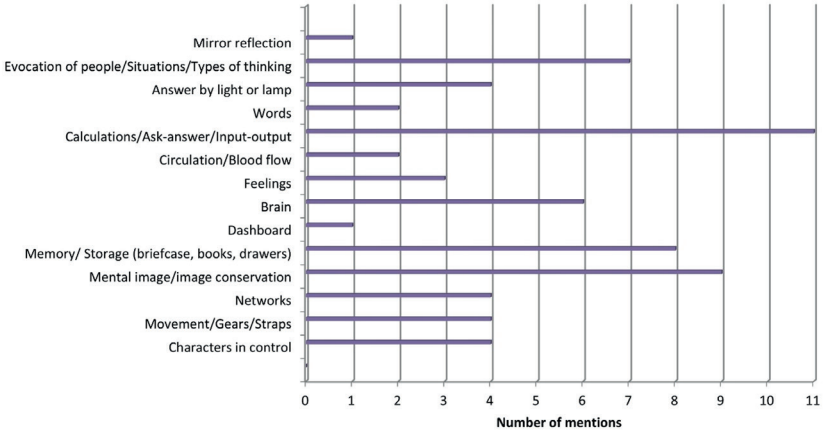


Figure 5
Representation of
a 5-year-old student

Some constants emphasized in the original work show that the different key ideas (Table 2) deduced from the expressed contents are present at all ages and that individual variations within the same class and within the same age are considerable. These variations were also detected in our study and are presented in Graph 2.

Graph 2
Key ideas mentioned presented by age



Source: Written by the authors.

The key idea of 'energy' whose typical content refers to power plants, motors, batteries, the electrical flow that appeared in the original study, was not identified in any of the representations of the Brazilian students. However, in the key idea of 'storage', it was necessary to add a new typical content to represent the storage outside the head (Graph 3).

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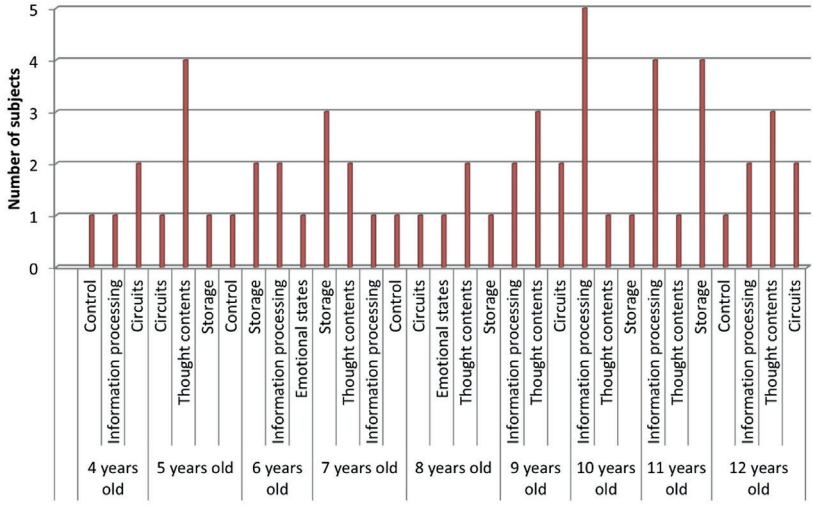
Some students reported that the information was stored in a literal cloud next to the head (Fig. 4).

Graph 3
Typical contents mentioned during the interviews



Source: Produced by the authors.

Among the youngest children interviewed in Geneva, content and states of thought are especially expressed. Among Brazilian children aged 4 to 6 years, in addition to thought contents, references were made to circuits (Fig. 6), storage, and information processing (Graph 3).

Figure 8
Representation
of an 12-year-old student

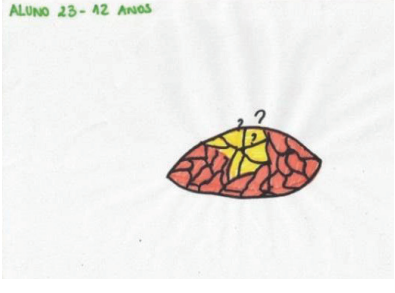
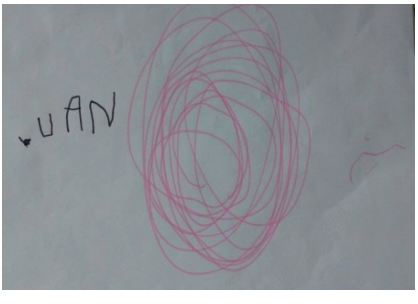


Figure 9
Representation
of a 5-year-old student



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The key idea most reported among Brazilian respondents was the 'handling of information', specially between the ages of 10 and 12. Within this classification of the idea of 'information processing', the most cited typical contents are input and output, question and answer (Fig. 7), and calculation.

The typical contents that had the least representations were the control panel (Fig. 8) and the reflection in the mirror. The representation of thought employing light or lamp was mentioned among younger children and persisted in the explanations of some interviewees up to twelve years old (Fig. 5). This permanence of misunderstood concepts is discussed in the work of Giordan and Vecchi (1996).

Figure 10
Representation
of an 11-year-old student

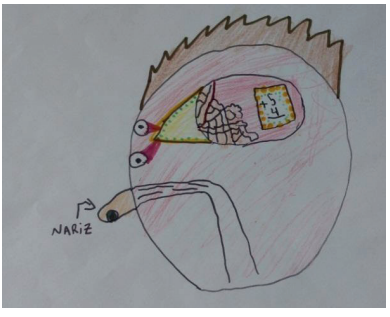
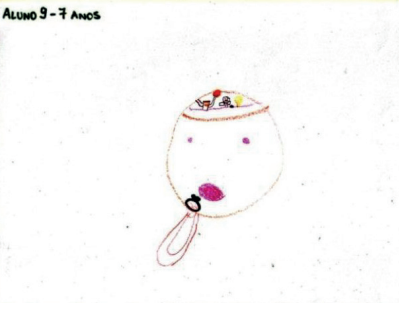


Figure 11
Representation
of a 5-year-old student



Martins and Eichler (2020) carried out the research in Science and Biology textbooks distributed in Brazilian public elementary and high schools, where they analyzed approaches to consolidate the nervous system in teaching materials. In this way, the typical contents needed in the original research and, also, in the current, are present in the reference models used by the authors of these textbooks to explain the functioning of the nervous system.

Like Jiménez, Prieto, and Perales (1997), who also analyzed textbooks that addressed the nervous system, Martins and Eichler (2020) identified that the reference models used indicated hydraulic models, telephone exchanges, electric currents, electrochemical machine, mirror, location mosaic, computer (informatics) or self-organizing model to explain the structure and functioning of the nervous system.

As Clément, Mouelhi and Abrougui (2006) point out, our scientific knowledge about the human brain and its functions has been renewed very quickly, also reflecting in its teaching, according to the evolution of social practices related to health and social behavior, in that underlies the development of values. In their didactic research, these authors

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tried to identify the interactions between values, social practices and scientific knowledge through a critical analysis of curricula and textbooks for secondary education in natural sciences in France and Tunisia. The results show a great variability of conceptual and epistemological approaches. Although some programs have introduced, with the concepts of epigenesis and brain plasticity, the biological bases of constructivism, more traditional values are also present. Many manuals are still limited to behaviorist theses, where, for example, the hereditary (which reduces the emergence of the brain to genetic determinism) is very present in textbooks, either in a more or less explicit way.

Knowing the influence of adults and schooling on the development and acquisition of knowledge by children it's possible to infer that technological advances and access to information provided to new generations have not overcome the influence of the pedagogical material used to study this topic. Therefore, as similarities found in the representation of Genevese and Brazilian children, even in such a significant time interval between them, and in research with different proposals, it only demonstrates the importance of the discussed topic.

Drawing a correlation between this study and Piaget's research on the notion of thought in his book *Representation of the World in Children* (Piaget, 2005), the first stage wasn't identified, in which children believe that one thinks "with the mouth", that the thought is identical to the voice and that nothing happens in the head and the body. For Piaget (2005), this stage occurs in children approximately with 6 years.

The second stage identified in the work of Piaget (2005) is marked by adult intervention. At this stage, which occurs on average at 8 years old, the child has already learned that one thinks with the head; sometimes it even alludes to the 'brain'. The child imprints material quality on thought and expresses it in the form of air, or blood, or a ball, etc. During the interviews carried out with Brazilian students, this stage appeared from the age of 4 and remained until 12 years old. There is no child classified as the third stage, where the average age is 11-12 years and marks the dematerialization of thought.

Conclusions

The illustrations of Brazilian students showed many similarities with those of students interviewed in Geneva as described, demonstrating that children's beliefs about the topic addressed in this article remain

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constant. On the importance of the influences of these reflections, 'meta-representations', for the cognitive and social development of children, Saada *et al.* (1996) contribute by stating that:

> It's believed that the child doesn't only have first-order mental states – namely, intentions, desires, goals – but also second-order mental states – namely, beliefs and a reflection on his own and those of others. These second-order mental states are commonly called "meta-representations". It's postulated that they exert an important influence, on cognitive and social development, including the acquisition of spoken and written language, moral judgment, memory, and social interaction in problem-solving (p. 91; our translation).

It is possible to see, through this study, the great relevance of this discussion for the context of philosophies of mind, science education, teacher training, and research on developmental psychology.

Finally, it can be indicated that a unified and common theory of the mind, its functioning, and its development with advancing age has not yet been developed. Furthermore, awareness of the workings of the mind requires the ability to reflect on your reflection, which is less developed in young children. However, as we have been able to demonstrate, despite several studies on representations of children, they can have specific and relatively elaborate ideas about the mind without being able to translate them into drawings or models. Despite that, observing the diversity of children's representations, it can be said, as Mein (1998) suggests, that our brain will remain an 'extraordinary garden' for a long time.

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Document reception date: December 15, 2021
Document review date: March 10, 2022
Document approval date: May 5, 2022
Document publication date: July 15, 2022

Sophia 32: 2022.

ISSN impreso:1390-3861 / ISSN electrónico: 1390-8626, pp. 137-160.