UNIVERSIDADE CATÓLICA PORTUGUESA

COMPETÊNCIAS MATEMÁTICAS EMERGENTES: DESEMPENHO NEUROPSICOLÓGICO DE CRIANÇAS EM IDADE PRÉ-ESCOLAR

EMERGENT MATH SKILLS: NEUROPSYCHOLOGICAL PERFORMANCE IN PRESCHOOL-AGED CHILDREN

Tese apresentada à Universidade Católica Portuguesa
para obtenção do grau de doutor em Ciências da Saúde (na especialidade de Neuropsicologia)

por

Joana Maria Rodrigues Rato

Instituto de Ciências da Saúde
Novembro de 2013

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Sob orientação de Alexandre Lemos de Castro Caldas

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Rato, Joana Maria Rodrigues
Competências matemáticas emergentes: Desempenho neuropsicológico de crianças em idade pré-escolar *[Emergent math skills: Neuropsychological performance in preschool-aged children]*. Lisboa: Universidade Católica Portuguesa: Instituto de Ciências da Saúde, 2013.

Tese de Doutoramento: Instituto de Ciências da Saúde da Universidade Católica Portuguesa
Orientador: Professor Doutor Alexandre Castro Caldas
Palavras-chave: Neurociência educacional, avaliação neuropsicológica, funções executivas, numeracia emergente, idade pré-escolar.

FCT Fundação para a Ciência e a Tecnologia
MINISTÉRIO DA EDUCAÇÃO E CIÊNCIA

A elaboração desta tese foi apoiada pela Fundação para a Ciência e a Tecnologia, através da bolsa de doutoramento na área de Psicologia com a referência SFRH/BD/46767/2008.

RESUMO

O presente trabalho insere-se no âmbito do emergente campo científico da Neurociência Educacional (também conhecida como Neuroeducação) e está organizado em duas principais abordagens, nas quais se estudam duas populações diferentes. A primeira abordagem subscreve a recomendação internacional sobre a importância de adotar uma visão da neurociência educacional para resolver alguns dos problemas educacionais. Nesta linha, uma pesquisa nacional foi realizada para analisar o conhecimento neurocientífico dos professores e as suas percepções sobre o significado da "ponte" entre a neurociência e a educação. Assim, dois estudos originais foram projetados para fornecer informação sobre o conhecimento dos professores e as suas crenças sobre o recente campo científico da neurociência educacional. Neste caso, a amostra coletada foi junto de professores do ensino pré-escolar ao ensino secundário [Estudo 1: Amostra com 627 professores de diferentes áreas de especialização com idades entre 25 e 65 anos (M = 41, DP = 9); Estudo 2: Participaram 583 professores com idades entre 25 e 61 anos (M = 41, DP = 9)]. A segunda abordagem refere-se à avaliação neuropsicológica e aborda um dos principais problemas atribuídos pela comunidade científica – os escassos instrumentos de medida (adaptados para o Português) para avaliar vários domínios neuropsicológicos. Três estudos experimentais foram realizados e um protocolo de avaliação neuropsicológica foi desenvolvido para este fim. Funções executivas, memória de trabalho visual-espacial, contagem dos dedos, percepção de pequenas quantidades sem proceder à contagem (*subitizing*) e a habilidade de usar funcionalmente os dedos e de os representar mentalmente (*finger gnosis*) foram os domínios trabalhados, a partir dos quais foram analisadas as suas relações com as competências matemáticas emergentes. Aqui, a população estudada foram crianças com idade pré-escolar [Estudo 3: Amostra composta por 137 crianças dos 3 aos 5 anos (M = 60, DP = 9; em meses); Estudo 4: Os participantes foram 30 crianças com 5 anos de idade (60-71 meses, M = 68, DP = 2.78); Estudo 5: Participaram 35 crianças com 5 anos de idade (M = 67.26, DP = 5.43), em meses]. Cada grupo de estudos experimentais, ou seja, os estudos correspondentes a cada abordagem, foram precedidos por revisões de literatura. Assim, são três os objetivos estruturais desta tese doutoral: (i) determinar se as perspectivas dos professores sobre a relação entre neurociência e educação (e seu conhecimento neurocientífico) dá a este campo científico a importância merecida (Estudos 1&2), (ii) adaptar para o Português o teste *The Shape School* para a sua utilização com crianças pré-escolares (Estudo 3), (iii) determinar se as capacidades matemáticas emergentes (pelo sistema do número aproximado e pelo conhecimento numérico) de crianças com idade pré-escolar é facilitada pelas funções executivas, memória de trabalho visuo-espacial, contagem de dedos, *subitizing* e a habilidade de usar funcionalmente os dedos (Estudos 4&5). Quanto aos resultados obtidos, na primeira abordagem, os estudos 1 e 2 fornecem evidências do interesse dos professores e do seu reconhecimento sobre o potencial da investigação neurocientífica na educação. No entanto, verificou-se também uma lacuna entre este interesse demonstrado e a proficiência na interpretação de informação científica, uma vez que os professores mostraram dificuldade em distinguir mitos de factos neurocientíficos. Os mitos "inteligências múltiplas", "ensino dirigido aos estilos de aprendizagem (modelo *VAK-Visual, Auditory, Kinaesthesic*)" e "lado esquerdo do cérebro contra o lado direito do cérebro" foram os mais prevalentes. Os estudos desenvolvidos destacaram a importância de um processo de translação para que professores e neurocientistas possam colaborar. Em relação à avaliação neuropsicológica, ou seja, a segunda abordagem aqui tratada, os resultados do estudo 3 permitiram obter a adaptação Portuguesa do teste *The Shape School* que se revelou adequado para utilização quer em investigação, quer em contextos educacionais e clínicos. Com os estudos 4 e 5 identificaram-se os componentes que se relacionam com as competências matemáticas emergentes, destacando-se as funções executivas, *subitizing* e *finger gnosis* como preditores do conhecimento numérico. Assim, os vários estudos realizados neste âmbito suportam a necessidade de avaliação precoce dos domínios neuropsicológicos analisados, visto que parecem contribuir para uma melhor caracterização das competências matemáticas emergentes em crianças com idade pré-escolar. Considerando todos os resultados no seu conjunto, as conclusões destacam a necessidade de validade científica para a reforma do ensino, em geral, e para a educação da matemática, em particular, sob o campo da neurociência educacional.

Palavras-chave: Neurociência educacional, neuromitos, professores, avaliação neuropsicológica, funções executivas, numeracia emergente, crianças de idade pré-escolar.

ABSTRACT

The present work falls within the emerging field of Educational Neuroscience and is organized around two main approaches, studying two different populations. The first approach subscribes the international recommendation concerning the importance to adopt an educational neuroscience view to solving some of the educational problems. In this line, a national research was conducted to analyse the teacher's neuroscientific knowledge and their perceptions about the "neuroscience-education bridge" meaning. Thus, two original researches were designed to analyse the teachers' knowledge and beliefs concerning educational neuroscience. In this case, the sample collected was the Portuguese teachers from preschool to high school [Study 1: Sample with 627 teachers with ages ranged between 25 and 65 years (M=41; SD=9); Study 2: Participated 583 teachers from different areas of expertise, aged between 25 and 61 years (M=41; SD=9)]. The second approach refers to the neuropsychological assessment and addresses one of the main problems assigned by the research community – the few tools (adapted to Portuguese) to evaluate several neuropsychological domains. Three experimental studies were performed and a neuropsychological assessment protocol was developed for this purpose. Executive functions, visual-spatial working memory, finger counting, finger gnosis and subitizing were the studied domains, which were then correlated with early number knowledge. Here, the population studied was the Portuguese preschool-aged children [Study 3: Sample composed of 137 children from 3 to 5 years (M=60; SD=9; in months); Study 4: Participants were 30 children with 5 years-old (60-71 months; M=68, SD=2.78); Study 5: Collected 35 children with 5 years-old (M=67.26, SD=5.43), in months]. Each group of experimental studies, i.e., concerning each approach, were preceded by literature reviews. Therefore, the structural goals of this thesis are threefold: (i) determine whether the Portuguese teachers' perspectives on the relationship between neuroscience and education (and their neuroscientific knowledge) gives to this field the significance deserved (Studies 1&2); (ii) adapt *The Shape School* test for the use of Portuguese preschoolers (Study 3); (iii) determine whether the emergent mathematical ability (by the approximate number system and the number knowledge) of Portuguese preschoolers is facilitated by the executive functions, visual-spatial working memory, finger counting, subitizing and finger gnosis (Studies 4&5). Concerning the findings, in the first approach, present studies provide evidence of the teachers' interest and acknowledge of the potential of neuroscientific information in education, but also found a gap between their interest and proficiency in the interpretation of scientific information, since they showed difficulty of distinguishing myths from facts. Regarding the neuropsychological assessment, i.e., the second approach discussed here, the current studies support the need for early assessment of the components abilities analysed, which seem to contribute to a better characterisation of emerging numeracy skills in preschoolers. Taken all together, the conclusions highlight the need of scientific validity for reforming education, in general, and mathematics education, in particular, under the field of educational neuroscience.

Keywords: Educational Neuroscience, neuromyths, teachers' beliefs, neuropsychological assessment, executive functions, emergent math skills, preschool-aged children.

ACKNOWLEDGEMENTS

First and foremost, I would like to extend my gratitude to my Ph.D. supervisor, Professor Alexandre Castro Caldas. Without his support and guidance, in the right moments, probably it would have become a never-ending work. I am especially thankful to Fundação para a Ciência e a Tecnologia (FCT) for funding my Ph.D. studies that allowed such a personally desired accomplishment.

I am also very grateful to all the teachers and children that participated in the several researches, making me believe that it is still possible to do science in Portugal.

A big thank you to my friends and colleagues, Sandra Fernandes, Ruth Ferreira, Daniela Ruivo, Pedro Seco, Jorge Ferreira, Stella Aguiar, Ana Maria Abreu and Lília Marcelino for their encouragement as I completed each step along the way to finishing this journey. I could have never asked for a better cheering section.

Personally, this would have never been possible if it were not for the unconditional love and support of my husband, Diogo. He was my best confidant and reviewer. I will be forever grateful for his patience and for always instigating laughs in our days.

I want to thank to my parents, Natália and Luís, for instilling in me a desire to be a lifelong learner and to my brother, Pedro, for never letting me give up. A special thanks to my mother for her personal effort in taking care of our "treasure" in his (so unique) first year of life. The well she took care of him took out a weight of my conscience and reassured me that I could successfully complete this goal.

It is with tremendous love that I dedicate this dissertation to my son, Dinis Rato dos Santos, with my appreciation by the meaning and hope that brings to the future.

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1 INTRODUCTION

There are few doubts that neuroscience can reveal important insights into how the brain works in education scenario. However, until recently, most of the explanations of learning processes seems restricted to the brain level, and are therefore on a different level than behavioural explanations provided by educational research (Schumacher, 2007). Many authors have agreed with the urge of combining neuroscience and education and it should be regarded as a two-way street with important impacts in both directions rather than a one-way street with neuroscience only informing education (e.g., Turner, 2011).

One domain in which the combination of neuroscientific and educational research has been a matter of intensive debate is mathematics education (e.g., De Smedt et al., 2010, 2011; Grabner and Ansari, 2010).

This program of research emerges on the base of this combination of educational neuroscience and mathematics education and will be directed to the neuropsychological assessment on early math aptitudes.

1.1 SCOPE OF THE WORK

The present Ph.D. work was drawn from advances in cognitive psychology and neuropsychology, and is strongly supported in the field of educational neuroscience, also known as “neuroeducation”, “brain, mind and education” or “neuroscience and education”. All the developed studies were triggered by a newly sight of learning process brought by the advent of educational neuroscience, a transdisciplinary exercise emerging from cognitive neuroscience and educational psychology.

Despite its apparent infancy, it is clear that the bridge between neuroscience and education has often failed in the past (Hirsh-Pasek and Bruer, 2007). An increasing number of researchers seem to agree that it is at least worthwhile to seriously consider potential implications of neuroscience for education (e.g., Ansari, De Smedt and Grabner, 2012; OECD, 2007; Spitzer, 2012; Szücs and Goswami, 2007) rather than dismiss the combination of these fields as “a bridge too far” (Bruer, 1997). This observation is also documented by the increasing support to combine neuroscience and education at the institutional level (e.g., through establishing special interest groups as the "Neuroscience and Education" group of the European Association for Research on Learning and Instruction -EARLI; "Brain, Neurosciences, and Education" of the American Educational Research Association -AERA, and the International Mind, Brain and Education Society -IMBES). This movement might be motivated by the notion that the impact of neuroscience for education is not as straightforward as previously believed. The promising path has been widely discussed, but there are still many problems on this scientific branch. The miscommunication between researchers and teachers or the misunderstandings of neuroscientific findings are some of the examples. The barriers that can obscure the success of this field are studied in this work.

The empirical research at the intersection of neuroscience and education has been expanded into many educational domains. Recently, the area being most extensively studied is (early) numerical learning (e.g., Ansari and Dhital, 2006; Kucian et al., 2006; 2011; Szücs and Goswami, 2007; Obersteiner et al., 2010), which is precisely the focus of the present dissertation.

Although the work presented embraces the new field of educational neuroscience, there are two main approaches and two target populations highlighted.

The first approach subscribes the international recommendation concerning the importance to adopt an educational neuroscience view to solving some of the educational (theoretical and practice) problems (Goldin et al., 2013). In order to understand if the Portuguese teaching community is prepared to receive the educational neuroscience challenge, a national research was conducted to analyse the teacher's neuroscientific knowledge and their perceptions about the "neuroscience-education bridge" meaning. In this case, the sample collected was the Portuguese teachers from preschool to high school.

The second approach refers to the neuropsychological assessment and addresses one of the main problems assigned by the research community – the few tools (adapted to Portuguese) to evaluate several neuropsychological domains. Executive functions, visuo-spatial memory, finger counting, finger gnosis, subitizing and number knowledge were the worked domains. Here, the population studied was the Portuguese preschool-aged children. There is a growing recognition (by the neuroscientists) that preschool education provides a firm foundation for later school learning (e.g., Jordan et al., 2009, Melhuish et al., 2008), but unfortunately it is not being an area of election of the Portuguese Educational System. With this work is expected to address some critical questions, e.g., Does a more distinct mental representation of the fingers also means a good performance of number knowledge in preschoolers? Do component abilities, such as executive functions, finger gnosis or subitizing, predict early number knowledge?

Therefore, the structural goals of this thesis are threefold: (i) determine whether the Portuguese teachers' perspectives on the relationship between neuroscience and education (and their neuroscientific knowledge) gives to this field the significance deserved (Studies 1&2); (ii) adapt *The Shape School* test for the use of Portuguese preschoolers (Study 3); (iii) determine whether the emergent mathematical ability (indexed by the approximate number system and the number knowledge) of Portuguese preschoolers is facilitated by the executive functions, visuo-spatial working memory, finger counting, subitizing and finger gnosis (Studies 4&5).

1.2 SUMMARY OF FOLLOWING CHAPTERS

The introduction presented in Chapter 1 gave an overview of the main issues under study and showed the structure of the dissertation.

Chapter 2 will deal with the educational neuroscience theme, in which is presented the state of the art and the data analysis related to the studies developed, concerning the teachers' perceptions and knowledge about this new field. Thus, chapter 2 includes one review and two empirical studies.

Chapter 3 presents the studies that support the title of this dissertation, i.e., the neuropsychological assessment on early math skills in preschoolers. This chapter starts with a review of the literature, which includes the description of the neuropsychological assessment protocol built for this program of research. In the following sub-chapters, the necessary background theory, statement of the problem, methodology, results and discussion are reported in each of the three experimental studies developed.

Conclusions, limitations and future work are presented in Chapter 4.

In sum, this dissertation includes a total of seven [7] articles, that is two [2] literature reviews and five [5] original researches. Four [4] of these articles are already published and the remaining three [3] are submitted.

2 EDUCATIONAL NEUROSCIENCE: CURRENT MISCONCEPTIONS AND FUTURE CHALLENGES.

2.1 NEUROSCIENCE AND EDUCATION: REALITY OR FICTION? [Review 1] *

*The following review has been adapted from: Rato, J.R., and Castro-Caldas, A. (2010). Neurociências e educação: Realidade ou ficção? In C. Nogueira, I. Silva, L. Lima, A. T. Almeida, R. Cabecinhas, R. Gomes, C. Machado, A. Maia, A. Sampaio & M. C. Taveira (Eds.) *Actas do VII Simpósio Nacional de Investigação em Psicologia* (pp. 626-644).

Abstract

The high number of publications recently released, has revived the discussion about the relation between the neuroscience and educational sciences. Nevertheless, there are still barriers that continue to postpone the success of this partnership leading to the redefinition of distinct and independent contributions of both scientific areas. The spread of myths darkening the progress made by cognitive neuroscience in different relevant areas concerning education has been one of the main problems. This essay aims to present the main questions that are debated around this relation. Also, it aims to clarify the misinformation still existing, as well as to arouse the need and urgency of a future cooperation between brain sciences and education.

Keywords: Cognitive neuroscience, education, neuromyths, brain, learning.

Introduction

In the U.S.A, the 90´s have been proclaimed as the "Brain Decade". This designation was conducted by neuroscience investigations with clinical proposals to find effective intervention against insanity (Varma, McCandliss, and Schwartz, 2008; Jones and Mendell, 1999). Throughout these years, many discoveries were made about brain mechanisms. Thus, there are still many questions waiting for an answer. Recently, thanks to a vivid curiosity by educational experts (e.g., Greenleaf, 1999; Jensen, 2000), the importance of some of these researches (mainly on perception, concentration and memory), has been highlighted as well as on how they could be informative to education. In a simple way, it is possible to characterize neuroscience as the brain science and education as the science of teaching and apprenticeship. Considering the importance of brain in the process of knowledge it is obvious the strict relation between neurosciences and education. However, mainly in the scientific field, not everything is easy or simple to define, nor obvious to associate. Experts have been trying to marry neuroscience and education since the mid 60´s (Willingham, 2009).

Twenty five years ago experts considered the creation of 'neuroeducators' following the argument that it would be by means of the study of the brain that the work of teachers could be transformed and improved (Cruickshank, 1981). Although it is not new that neuroscientific research can influence pedagogical practice and theory, these days brought new scientific research that enables the link between neuroscience and education.

The discussion of the issue is open and while some authors believe that brain science and education were made to complement each other, others criticize and question the durability and the real benefit of this possible alliance. The classic experts argue that it is premature to relate biology to education and it is necessary to find answers to serious questions connected to brain mechanisms above all. Other scientists arduously disagree and support that the investigation in pedagogical contexts will shape big discoveries in the basic biology range and cognitive processes of knowledge and development (Fisher et al., 2007).

Meanwhile, what appears to be a clear relation immediately turns out to be obscure when taking into account politics, culture, history and ethics (Sheridan, Zinchenko, and Gardner, 2005; della Chiesa, Christoph, and Hinton, 2009). Throughout history, science and education have followed different paths, although these have been always connected and had great influence upon society. Philosophically, the values through which they act are constantly opposite to each other and epistemologically have relied on different conceptualizations (Samuels, 2009).

The study of learning process inevitably joins education and neuroscience (Goswami, 2004). Cognitive Neuroscience tries to understand and explain the relation between brain, superior mental activities and behaviour. This new subject of Neuroscience focuses its study on the relation between the neurological mechanism and the psychological activity focusing especially on behaviour analysis as a manifestation of the central nervous system activity (Posner and Rothbart, 2005). Learning respects neuroplasticity and can be understood as a process through which the brain nervous system rebuilds its ways of information processing and representation (Geake and Cooper, 2003). Considering the results of various studies, there are no doubts that certain learning interference find their best characterization in neuropsychological investigation. Dyslexia case is a good example and it is documented that educational and behaviour sciences consider that the difficulty of reading depends on the lack of visual perception, while cognitive neurosciences studies identify lexical phonology as the main problem concerning this issue, clearly showing the brain dysfunction areas that justify the etiology of disorder (Shaywitz and Shaywitz et al., 2001).

Willingham (2008) claim that some learning disturbances reveal a detectable neural base that provides reasons to be optimistic in relation to neuroscience measures, and believe that in a near future we will have tools able to establish a trustworthy diagnostic. The connection between neuroscience and education has called curiosity not only by research and scientific community, but also among educational policy makers and other education professionals. It has been given relevance to the impact that neuroscience can have on education, giving special visibility to investigations in the area of cognitive neuroscience, whose application from theory to practice can be projected to education. However, the real contribution of neuroscience to education continues to be the main issue.

The National Research Council Report (2005) concludes that children's education is not maximizing children's cognitive capacities/skills in formal or informal contexts. There is definitely increasing criticisms on Piaget's work (e.g., Björklund, 1997; Hannon, 2003). However, what seems to be more impressive is the fact that neuroscientists do not find in educational literature many reliable references about brain and new scientific developments. The OECD (Organization for Economic Cooperation and Development) Report 'Understanding the Brain. Towards a New Learning Science'(2002) as resulted in one of the first attentions to this situation, once it suggests a transverse subject investigation in order to create bridges between brain sciences and educational sciences (Jolles et al., 2006; Nes and Lange, 2007).

Lately, the number of articles that link neuroscience to education from a theoretical point of view have increased, but few consider the practical interest of neuroscientific results in behaviour theory (Willingham and Lloyd, 2007).

Neuromyths on education: From confusion to dismythification

According to recent literature, many are the problems that are found in the interface between neuroscience and education. Firstly, what really complicate the success of this interrelation are the false interpretations given from the neuroscience studies that consequently give rise to "neuromyths" (e.g., Goswami, 2004; Howard-

Jones, 2008; Mason, 2009; Christodolou and Gaab, 2009). The concept of neuromyth was launched by OECD (2002), denouncing the danger of the excess of interpretation upon neuroscience investigations (Purdy, 2008).

During the last years, many false brain concepts have been circulating. Since the moment that brain skills have become tabloids of newspapers and front pages of general magazines, popularizing some of the studies done on the area, it turned out to be important to distinguish what is scientific from what is pure speculation. The use of only 10% of the brain; the left and right functioning parts of the brain as parts working independently; multiple intelligences; learning methods based on multi-sensorial pedagogy (VAK model); drinking a lot of water as a way of improving the learning process, are examples of the most popular neuromyths.

The idea that "we only make use of 10% of our brain" could not be more erroneous. Nowadays, through neuroimaging, it is possible to check the functioning of all parts of the brain. This false assumption has even led some experts to search the origin of the myth (Beyertsein, 1999; Nyhus and Sobel, 2003). Beyertsein (2004) was one of the neuroscientists who were most indignant, calling the attention that among millions of brain studies, no one ever found a part of the brain that has never been used.

The myth "left side of the brain *versus* right side of the brain" has probably its root in hemispheric specialization studies when locating different skills (left-brain responsible for language and right-brain responsible for abstract thinking) ignoring all the considerations from numerous studies (Goswami, 2004). According to several authors, many aspects of language processing are in fact located on the left side but the language processing does not only occur on the left-brain (Thierry et al., 2003). Experiences with blind people or people who emigrate after their childhood inserted in a new linguistic community are excellent examples of how exception does exist. From Hellige's point of view (2000) we have learned so much of left/right brain separately that it is time to join these parts (Geake, 2008).

The model of multiple intelligences (Gardner, 1993) which divides cognitive skills in seven intelligences is a perspective that must be crossed. It is normal that heterogeneity exists in abilities. The fact is that these specific abilities of individuals are positively correlated (Carroll, 1993; Duncan, 2001).

Despite all evidence, the educational community has been surrounded by strengths of multi-sensorial standards of learning (visual, auditive and kinesthetic stimulation). The deep purpose embracing this pattern designated by VAK – Visual, Auditory, and Kinesthetic (Dunn, Dunn, and Price, 1984) is based on the information obtained by a sensorial modality and are processed in the brain to be learnt in an independent way far from the information received by other sensorial means. Some crossed models criticize this pattern considering that it is not sufficient and adequate (Geake, 2008).

There is not concrete evidence which associates directly water consumption to a more effective process of knowledge. In fact, drinking water brings benefits to body namely in what concerns hydration, essential to a good body regulation and functioning. Considering the classroom perspective, it can also create short breaks helping concentration performance but beyond this there is the principle of extrapolation. (Schultz, 2009).

The spread of these myths obscured the progress done by cognitive neuroscience in several different areas of education (Geake, 2008).

Many of these myths also show data based on scientific research turning them even more difficult to dispel. Some are incomplete as a result of overreaction or are completely false. So, it is important to dispel more damage and prejudice to the educational system (OECD, 2007). This sprawl was due to the expansion of educational programmes initially based on brain study, known abroad by brain based pedagogies (Geake and Cooper, 2003; Goswami, 2006) or Brain Gym (Howard-Jones, 2007), popular in eighty countries and considered `pseudo-science´ by various scientific societies (Howard-Jones, and Pickering, 2006).

Most ideas based on these programmes have already been included in the pedagogical culture/context of some schools which constitutes a fact that has worried some neuroscientists. Recently, in a conference organized by the University of Cambridge, teachers claim that they were encouraged, by mail, to participate in courses to learn how to apply and enforce brain training programmes (Goswami, 2006). According to a survey done in the United Kingdom, about thirty per cent of the teachers have already heard about "Brain Gym" (Pickering and Howard-Jones, 2007).

Neural mechanisms influenced by specific physical exercise and the so wanted focus on balance between the left and right side of the brain are some ideas/principles sold by this programme. The expressions and pseudo scientific concepts used to explain how these works, have not been assessed by any scientific criteria not even have they been recognized by the neuroscience area (Howard-Jones, 2007). The only truth in this, is that students effectively have brain (Goswami, 2004; Fischer, 2009).

Discoveries related to the synaptic rapid growth in pre-school children´s brain have also supported the hope that cognitive skills can be increased through pedagogical development, meaning, education.

Supporters of the educational programmes have conveniently forgotten about the lack of experience in relation to the direct link between neurological and learning processes. It is far from being clear if children who are motivated to memorize isolated facts at the beginning of their life show better performance at retaining information in a long time period than their mates (Stern, 2005).

Scientists are known for using scientific terminology regularly only understood by other experts belonging to the same line of studies. This can also be a real holdback when distinct subjects are trying to interact. The scarce scientific material on brain investigation relevant to education which permits an easier understanding accessibility to non-experts, can in fact have contributed to the development of wrong conceptualization.

Disagreement prevailing in research about brain can equally contribute to confusion to who do not follow scientific research and its literacy. As a result, discoveries and non-discoveries are responsible for allowing the improvement of brain understanding, becoming a natural process inherent to scientific progress (Blakemore and Frith, 2009).

Another difficulty referred to in scientific scripts comes from limitations associated to brain imaging equipment. Although teachers are familiar with brain visualization techniques, they are not likely to know the way how those tools are used and contradictions were found by investigators to examine the brain in a definite way. The goal of using these tools/instruments have different is to remark brain structures and brain action but different instruments have different aptitudes (Willingham and Dunn, 2003; McCabe and Castel, 2008).

The use of this methodology leads us to other restraint linked up with lab results and impossibility of being applied immediately to the classroom context. Sometimes some observation conditions have specific requirements that are not productive at all to carry conclusions to a scenario such as an educational context.

Reading a book at school or at home is not the same as reading it in a lab knowing that you are doing it with a determined objective and, therefore, restraints are not avoidable in this situation as there are reaction timings’ (Fisher et al., 2007).

In reality, it is necessary to draw different analysis levels before having this transition made. Therefore, some authors examine different levels and identify that the educational theory works at a more distinct level than the one used in neuroscience (Willingham and Lloyd, 2007).

Educationalists do not study leaning at a cell level (Goswami, 2004). They are especially interested in analyzing behaviour over school performance like Reading and Maths. This is the reason why they give more importance to cognitive building processes such as memory, attention among others. Confusion starts when educational constructs generally embraces two or more cognitive constructs such as memory and attention.

The outline of behaviour and neural analysis proposed by Willingham and Lloyd (2007) show a hierarchical nature (upright dimension) as the majority of concepts are not balanced (horizontal dimension) (Figure 1).

Neural levels	**Behavioural levels**
	school
	classroom
central nervous system	individual mind
	educational construct
	cognitive construct
gross anatomic structure	
nucleus, cortical subregion	
neural network	internal representation or process
individual neuron	
Synapse	

Figure 1: Levels of neural and behavioural analysis (Willingham and Lloyd, 2007).

According to these authors’ view, there are significant behaviour effects which cannot be explained directly by neuroscientific results due to the lack of parallel analysis levels. Developing effective teaching methods on the basis of brain sciences can only be possible with different analysis standards. To this extent, a desirable investigation model entails overcoming at least five basic levels to make the transition of neuroscience to cognitive neuroscience, from psychology to pedagogy until reaching the classroom context (Tommerdahl, 2008).

To switch on the mind, Biology and Education together with researchers must leave the lab isolated context and move to the real life context leaving educational practice available to scientific appreciation (Coch and Ansari, 2009). Taking into account the premise that any alliance only reaches success when there are realistic expectations between the stakeholders, it appears to be vital that the first step is to fade away with many myths over prejudices among pedagogues and deflect the idea we must wait for neuroscience to provide with quick solution and that it should be descriptive.

Neuroscience and education: A relation with future?

Society has built many expectations in relation to what neuroscience can bring to Education. Therefore, some of those beliefs are completely unrealistic. It is possible to consider a trap claiming that neuroscientific investigation will, on its own, answer to all educational doubts (Fischer et al, 2007).

According with Blakemore and Frith (2003) the one-way approach can be dangerous and the answer seeking should not focus on the issue of how brain science is enforced to the educational practice but essentially what pedagogues need to know and how they can be informed and up-dated by neuroscientific research.

Fewer than ten years ago, Bruer (1997) enhanced that the relation between neuroscience and education could be rhetorically attractive but could also scientifically represent a distant bridge. For him, it is essential that there is this huge mindfulness in the attempt to make direct links between classroom learning and neuroscience. In addition, he points out cognitive psychology as a potential mediator to join brain science to education (Purdy and Morrison, 2009). Although cognitive psychology has its own implications on education, it is consensual among experts that this is the most suitable science to play the mediator role. Blakemore and Frith (2009) believe that by means of cognitive psychology, neuroscience can influence teaching and learning studies in a more deep and effective way. Due to their curricular education, educational psychologists seem to be in a better position to feel comfortable in both areas (Berninger and Corina, 1998; Schunk, 1998; Stanovich, 1998).

An interacted dialogue to avoid the dominance of one subject upon other has been widely referred. From Fisher and Immodino Yang's view (2008) the dimension of brain and science studies to education is significant. However, it is urgent to construct a new interdisciplinary science, in which each side play strong roles and that are clear the connections between both scientific fields. There are already some designations to this new scientific field. Some designate it by 'Mind, Brain and Education' (Fisher et al., 2007), others refer to the new era of science and education as an 'Educational Neuroscience' (Goswami and Szucs, 2007).

According to many authors, a simple combination of several subjects does not appear to be enough so that this assumption is reachable (Samuels, 2009; della Chiesa et al., 2009). In order to avoid that this approach would just be a transitory stage, and that it can succeed, pedagogues must know the brain science and scientists need to understand education in a deeper way.

Koizumi (1999) was one of the first authors to distinguish interdisciplinarity from transdisciplinarity and defends that it is only valid to generate new knowledge with the creation of a new transverse subject science. Moreover, this author defends that interdiciplinarity and multidisciplinarity influence each other and create intersections in two dimensions (Koizumi, 2004). Transdisciplinarity implies active cooperation between subjects leading them to a new independent subject assuming a three-dimensional level (Figure 2).

Therefore, we are facing a dynamic approach in which its conceptual structures are developed through the connection of completely different subjects. It is the result of the connection of these scientific fields that it is possible to create a new knowledge reaching specific questions (Samuels, 2009).

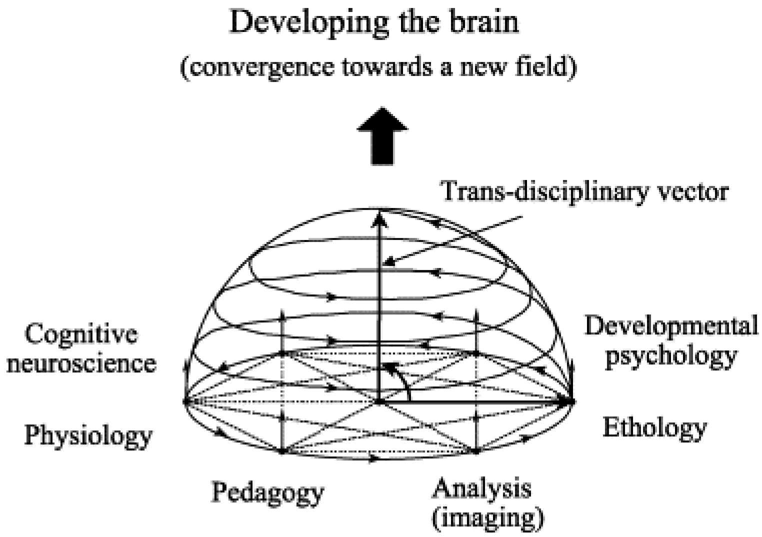

Figure 2: Transdisciplinarity (Koizumi, 2004).

Traditionally, research develops independently bearing in mind independent subjects (Koizumi, 2004). However, it is necessary to build a bridge between these subjects and boost the development of a new and broad scientific field which requires new methodologies and new research organizations. The model of Koizumi (1999) proved out to be a useful tool to clarify the fundamental assumptions of a new science because it not only reflects its initial structure (interdisciplinarity) but also its aim - transdisciplinarity (della Chiesa et al., 2009).

Inspired by this model the transversal subject project developed by OECD 'Learning Sciences and Brain Research' (1999-2007) brought numerous challenges starting with the resistance shown by some countries in what concerns its approval (della Chiesa et al., 2009). The main obstacle found by people responsible for this project has to do with managing dialogue between neuroscientific and educational communities. This unexpected setback was due to the difficulty in recognizing the implicit knowledge in its own field, and the intention was to turn it more explicit to their peers of other related areas.

The starting point to the mutual comprehension respects the use of vocabulary understandable to all neuroscientists and pedagogues. Investigation problems should answer to questions done by the team work in order to meet real problems occurring in educational contexts. An open discussion between neuroscientific and educational community (including parents and students) is vital to the development and consequent success of this new scientific field already considered one of the most important in the 21st century (Koizumi, 2004).

Between 2005 and 2006 the *Economic and Social Research Council* (ESRC) and the *Teaching and Learning Research Programme* (TLRP) successfully organized seminaries on the project *Collaborative Frameworks in Neuroscience and Education* in which teachers, neuroscientists, psychologists and politicians participated to discuss the potential of a cooperative work with the aim to lead the discussion to a mutual neuroscientific and educational comprehension (Goswami, 2006; Howard-Jones, 2008).

As future guidance, eco studies are pointed out. This is, investigation in educational contexts is relevant to sustain the dominance of brain/mind and education similar to what happens with medical research being essential that it happens in medical contexts/practice (Hinton and Fischer, 2008). In order to reach a strong scientific basis in teaching system and learning process there must be infra-structure changes. According to Fischer and collaborators (2009), the implementation of three factors became essential: investigation centres; shared data systems about learning and development; a new professional profile (engineers/ educational translators) to concrete the contact between investigation and educational practice easier.

Although neuroscientists have been discussing learning strategies for decades, an international movement is visible to formalize the connection between brain science and educational and learning science. Since the creation of *International Mind, Brain and Education Society* (IMBES) in 2004 together with its journal *Mind, Brain and Education* in 2007, this mission has gained importance and it has booted the collaboration among neuroscience, genetics, cognitive science and education researchers (Fisher, 2009).

The main goals of this movement are to encourage the dynamic interaction of scientific investigation and the educational knowledge and practical approach which joins educational sciences and neuroscience. From the moment that investigators start producing material for a better understanding of learning contexts, the possibility of having educational politicians and even teachers basing their practices and educational decisions on practical evidence instead of doing it upon opinions and ideologies increases (Fischer et al., 2007).

The *Japanese Society of Baby Science* and the 'Brain Neuroscience and Education' SIG from *American Educational Research Association* (AERA) are good examples of groups and activities that appear all over the world and which recognized the potentialities of a common future of brain and educational science suggesting it is the right moment for this collaboration to happen (Coch et al., 2009).

Huge organizations such as OECD also assume this approach of *Mind, Brain and Education* reinforcing its role to debate educational questions (OECD, 2007). There are positive perspectives towards this movement breaking the skepticism on several issues that it approves. After all, it rebuilds its own patterns by having this happened. There are even conferences being organized with the unique aim of studying neuroscientific developments of educational and public audience.

Mind, brain and education: The Portuguese movement.

The Portuguese context is still far from what is debated abroad. However, significant interest on the area is remarkable as it is the significant role of cognitive neuroscience for prior identification and intervention on various learning and behaviour problems. According to Castro Caldas (2007), “nowadays there is no doubt about the importance that cognitive neuroscience have in understanding the mental phenomena. The process of learning is definitely one of the most important chapters. (…) It seems urgent that some new information about the emerging chapter of knowledge is integrated in our teaching decisions. Each pupil has it is particular characteristics which we must analyse in detail” (p. 42).

Although the increasing attention dedicated to this topic, there is a small focus on studies concerning cognitive neuroscience in general and on neuropsychological assessment in particular. The little theoretical, practical and methodological investigation as well as the lack of specific patterned measurement instruments has constituted huge limitations for the national investigation in this area mainly in children and teenagers (Simões and Castro-Caldas, 2003; Simões et al., 2003).

Throughout this article, we try to explain different perspectives about the relation between neuroscience and education to make some barriers understandable and those which distance these two sciences mainly those which are tethered to scientific misinformation. We separate reality from fiction and analyze present questions never forgetting that many doubts can still emerge. With this revision we intend to cause the first gap on the wall separating brain sciences and educational sciences. Since is identified the main problems, there is the need to (re)act promptly as to block the diffusion of ideas or poor scientific material based on brain that do not contribute at all to children´s process of knowledge.

Considering the great study shortage at a national level on the area of learning mechanisms of learning processes following neuroscience, it is prevalent that Portuguese neuroscientific community considers these questions to create a profitable investigation either in educational or neuroscientific area. It is necessary to continue with the scientific movement 'Mind, Brain and Education' similar to what happens abroad.

We believe that it is through investigation development inside schools where we can assess scientific progress. This one ought to be followed by different qualified experts working at university research centres. As a result, we must bring effort together to reach a joint action between Schools (private and public) and University so that we can work on investigation in action projects with quality. Maybe one of the most important aspects is on the exchange of experiences and on the shared analysis of investigation problems. The more direct dialogue there is, little space there will be to wrong interpretation. This is an obvious advantage to both parts. Neuroscientists must be aware of the triggering erroneous conceptions and should invest even more on the advertising of scientific literature which points to the link between the sciences of brain and education.

It is crucial to clarify pedagogical programmes based on brain that teachers casually might want to use in their lessons without having to rely on neuroscientific research. Pedagogues must work together with researchers to develop and test many hypotheses about the working of mechanisms underlying to apprenticeship. The double side way of the classroom and the lab can be risky and long but taking into account its benefits it is certainly a trip that is worth it.

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2.2 ACHIEVING A SUCCESSFUL RELATIONSHIP BETWEEN NEUROSCIENCE AND EDUCATION: THE VIEWS OF PORTUGUESE TEACHERS [Study 1] *

* The following study has been published as: Rato, J.R., Abreu, A.M., and Castro-Caldas, A. (2011). Achieving a successful relationship between neuroscience and education: The views of Portuguese teachers. *Procedia - Social and Behavioral Sciences*, 29, 879-884.

Abstract

Educational Neuroscience is currently raising high attention by the educational and neuroscientific community. However, society has created too many expectations concerning what Neuroscience can bring to Education. With this study, we aim to identify eventual distorted expectations of the teachers and propose ways to overcome these. This study was carried out in Portugal with 30 participating schools, where 627 questionnaires were answered by teachers from Preschool to High School. Our results show that there are still misunderstandings concerning the Portuguese teachers' views about the links between Neuroscience and Education. More collaborative efforts between professionals of both fields are needed for the field of Educational Neuroscience to succeed.

Keywords: Educational Neuroscience; teachers view; teacher learning.

Introduction

There have been many attempts to "marry" Neuroscience with Education since the middle 60s (Willingham, 2009). The creation of 'neuroeducators' was first proposed 30 years ago, based on the belief that brain science might transform and improve the practice of teachers (Cruickshank, 1981). However, the role of Neuroscience in Education is still under discussion (e.g., Fischer, Goswami and Geake, 2010; Samuels, 2009).

For decades, mainstream education has gravitated around behavioral paradigms, reflecting the contribution of Cognitive Psychology (e.g., Piaget, 1952). Since there is no learning without the brain (Goswami, 2004), modern research on learning processes inevitably relates Education with Neuroscience. Thus, teachers face a new dilemma: How to unify Neuroscience and Educational theory and practice? Here, we designed a questionnaire to assess teachers' views concerning the relationship between Neuroscience and Education. With this study, we aim to identify putative distorted expectations and propose ways to overcome these.

Although some cultural and educational concerns may differ from country to country, those related to the widespread of distorted conceptions and expectations of teachers are becoming global. Much like in other countries, Portuguese teachers seem vulnerable to misconceptions and this vulnerability stems from the lack of knowledge and time for scientific updates (Rato, Abreu, and Castro Caldas, 2010).

Method

Participants

Our sample consists of 627 (474 female; 153 male) Portuguese teachers (Preschool to High School) from different areas of expertise (see Table 1). The age of our cohort ranged between 25 and 65 years (M=41; SD=9).

Table 1. Areas of expertise and educational stage of teaching.

Areas of expertise	Educational stage *					Total
	Preschool	Primary school	Elementary school	Middle school	High school	
Unspecified +	31	103				**134**
Language and social sciences						
Languages		6	20	39	26	**91**
History/Philosophy			18	23	37	**78**
Math and economics						
Mathematics			32	52	25	**109**
Economy				3	11	**14**
Natural science						
Biology	1		4	15	7	**27**
Sport and special education						
Sport education			14	23	17	**54**
Special education	9	20	7	3	1	**40**
Technology and arts						
Computer science				10	11	**21**
Visual arts/Music/Dance		7	27	15	10	**59**
Total	**41**	**136**	**122**	**183**	**145**	**627**

Note: * The education system in Portugal is divided into five key stages and mandatory for children from 6 to 17 years old. For each school phase we indicate the corresponding age: 3 to 5 years in Preschool; 6 to 9 years in Primary school; 10 to 11 years in Elementary school; 12 to 14 years in Middle school and 15 to 17 years in High school. + In the Portuguese Education system Preschool and Primary school teachers do not usually indicate an area of expertise because they teach several areas.

Recruitment was carried out in 30 participating schools from nine districts of Portugal and the Islands of Azores and Madeira. Our participants' teaching experience ranged from less than one year to 42 years (M=16; SD=10) and only 23% (N=147) were in training. Of these, 37% (N=54) were enrolled in post-graduate courses (e.g., Masters, PhD), 26% (N=38) focused their service training on their area of teaching and 21% (N=31) on computer science courses; of remaining participants in training, 15% (N=22) attended teaching methodology courses and 1% (N=2) attended neuroscience-related workshops.

Measures

We designed a questionnaire inspired by a study by Pickering and Howard-Jones (2007). In a preliminary set of queries, we assessed the importance attributed by teachers to the understanding of brain functions in educational practice. These initial questions aimed at investigating the attributions given by teachers that might influence their views on the relationship between Neuroscience and Education (Appendix A).

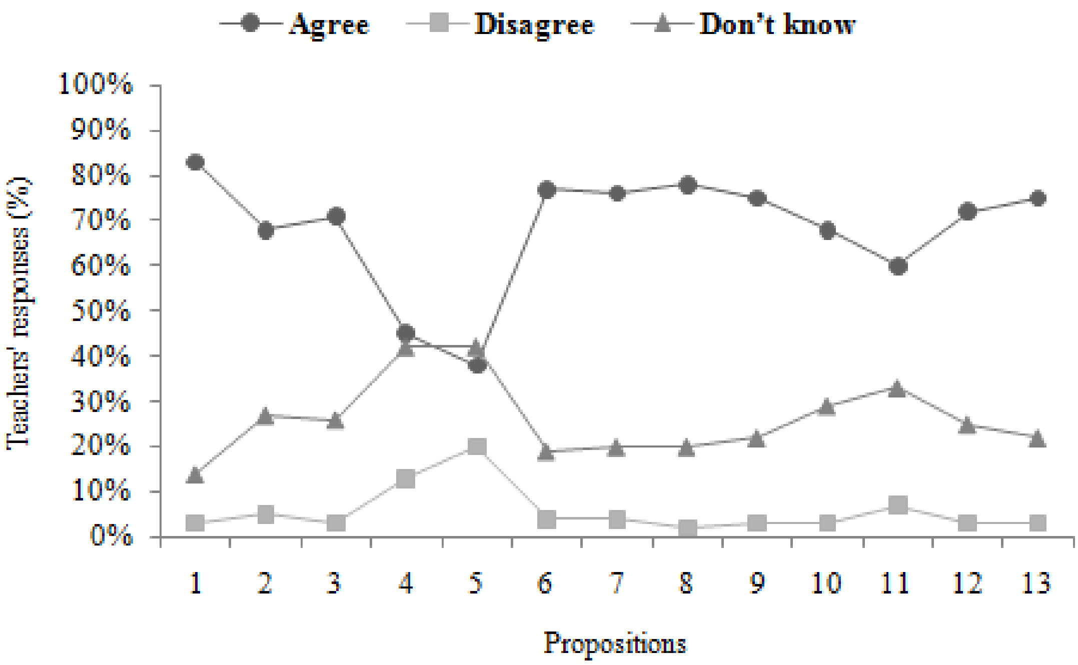
The aim of our questionnaire was to understand how teachers perceive the role of Neuroscience in Education, in order to identify eventual distorted expectations, a second subset of statements were presented and the participants were asked to agree, disagree, or to express lack of familiarity towards each statement presented. In order to assess if teachers had distorted or true expectations concerning how Neuroscience might contribute to Education, the statements were devised by selecting some of the issues most discussed in the literature concerning the potential of Educational Neuroscience (e.g., Christoff, 2008; Goswami and Szücs, 2010; Fischer, 2009).

Two of the 13 statements presented (referring to what might be necessary to achieve a successful relationship between Neuroscience and Education) are not recognized by the neuroscientific community and were added to assess the existence of possible false beliefs.

Results

According to our data, in the preliminary queries of our questionnaire assessing the importance attributed by teachers to several issues relating the brain and educational practice, 91% (N=571) of the teachers considered understanding brain function very important for an early screening of learning problems. Support for individuals with Special Educational Needs of various origins (e.g., cognitive with 93%) was also attributed high importance by teachers. The application of teaching strategies (87%; N=548), the design of educational programmes (83%; N=518), the decisions about curriculum content (78%; N=491), and the role of nutrition in educational performance (76%; N=478) were also considered important.

In the second subset of 13 statements, our results show that most teachers (83%; N=520) considered that a successful relationship between Neuroscience and Education depends on improved teacher training. The teachers' agreement with the suggested statements was widespread, with the exception of that suggesting the creation of a new transdisciplinary science; this statement obtained only 38% (N=235) agreement from the teachers, although 42% (N=266) were unsure. Teachers also agreed with the two misguided propositions - Neuromyths - that did not stem from neuroscience literature namely, the 'need for neuroscientific answers to all questions of education' (45%; N=282) and the 'need for more brain-based programs' (68%; N=428) (see Figure 1).



Note: 1. Further training for teachers; 2. Neuropsychologists as mediators to link brain science to education; 3. Research schools - more studies that interrelate a neuroscientific perspective with a school setting; 4. Neuroscientific answers to all questions of education*; 5. Creation of a new transdisciplinary science; 6. Shared vocabulary between neuroscientists and educators; 7. Debunking brain myths.; 8. Collaboration between schools and universities; 9. Two-way dialogue amongst educators and neuroscientists; 10. Spread of programs such as Brain Gym*; 11. Clarification of ethical issues in brain research; 12. Shared databases on learning and development; 13. Conferences involving neuroscientists and teachers. * indicates that this statement is not recognized by the neuroscientific community.

Figure 1. Teachers' responses concerning the 13 propositions suggested for achieving a successful relationship between Neuroscience and Education.

Surprisingly, no differences were found in the % of teacher's responses for each statement between the different areas of expertise, geography and years of practice (χ^2 (60) =35.29, p =.995 ; χ^2 (36) =15.73, p =.999 ; χ^2 (24) =14.09, p =.945, respectively).

Hence, the percentage of agreement is similar for each statement, regardless the areas, locations of teaching and years of practice.

Discussion

Teachers usually show interest in the brain research, although the educational literature poorly discusses the neuroscientific perspective (OECD, 2002). Anglo-Saxon studies of teachers' perceptions on the role of the brain in education revealed an academic enthusiasm operationalized by attempts to interrelate these fields. However, the conceptualizations concerning what this interrelation might entail were not the same for all (Pickering and Howard-Jones, 2007).

Our study revealed that Portuguese teachers also consider that neuroscience could be an ally of their work. Nevertheless, when asked about the importance of the understanding of brain functions in several aspects of educational practice, teachers consider every aspect important alike and do not make significant distinctions about, for example, the role that the brain might have on deciding curriculum contents or on the insights it might bring for intervention with children with Special Education Needs.

According to their responses to the provided statements, teachers acknowledged the need for further training in order to allow this new scientific field to succeed. This was the statement with the highest percentage of acceptance, which may indicate that teachers are attracted to how the brain works but have difficulties in transferring the existing neuroscientific findings to educational practice. Despite the realization that further training is needed to understand the links between Education and Neuroscience, the majority of teachers do not realize the need for a new discipline integrating these two areas. Perhaps introducing the study of Neuroscience in teacher training could dispel some confusions and act as a key factor to achieve a better flow of neuroscientific knowledge between researchers and educators.

Our results also revealed the teachers agreement with our (false) suggestion that the spread of brain-based programs would benefit the success of a neuroeducational field. This distorted expectations might stem from the non-scientific sources where Portuguese teachers look for information (Rato, Abreu, and Castro-Caldas, 2010).

According to our data, teachers show a similar pattern of acceptance of the statements presented, regardless of their area of expertise, location of practice or years of experience. This shows that the knowledge of these issues is no different between a

Biology or Language teacher, an experienced or trainee teacher, or a teacher from a large city center or a small town. All teachers seem vulnerable to false expectations and this is a sign that action must be taken to eradicate this reality of vulnerability.

As stated by Goswami (2004), educators do not study the learning process at the cell level. Considering the existence of different levels of analysis between Education and Neuroscience, it is imperative that teachers receive neuroscientific information in a relevant and accessible form. Hence, this information has to be clear to avoid misinterpretations.

Society has created too many expectations about what Neuroscience can bring to Education, being some of these beliefs totally unrealistic. It is an illusion to assume that neuroscientific research by itself, will respond to all education queries. This over-expectation concerning the answers given by the study of Neuroscience may be associated with the circulation of misconceptions promoted by popular brain-based educational programmes (e.g., Geake, 2008; Purdy, 2008).

Clearly, it is crucial to unmask the fake classroom applications, which claim to be (neuro-) scientifically based. These so-called brain-based "magic" teaching tools do not derive from Educational Neuroscience.

One way to overcome the misuse of neuroscientific research is to think beyond simple laboratory-to-classroom links and bet on a new discipline to bring together brain scientists and educators. We agree with the investment on neuroeducational research proposed by Howard-Jones (2010), which could be a path to enrich both scientific and educational understanding. Teachers must stop to question their role in this debate (Greenwood, 2009) and be part of it actively. Teachers can contribute to informing cognitive neuroscience research with their unrivalled practical knowledge (Szücs, 2005). Scientific discussions circumscribed to one's own field should come to an end. Scientific discussions require a larger participation of teachers at neuroscientific meetings and vice versa.

Presently, one of the challenges of Educational Neuroscience, and the trigger for its success, seeks the improvement of the scientific dialogue and a shared language in academic and neuroscientific circles. This requires professionals that master a shared communication across disciplines. Currently, it seems that no such professional is taking the lead at this role in Portugal. Our results show that there are still misunderstandings when teachers are questioned about the links between Neuroscience and Education. The bridge between Education and Neuroscience must have a two-way pathway and Educational Psychology could be the support needed to connect Neuroscience to Education (e.g., Berninger and Corina, 1998; Mason, 2009). While there are still few professionals specialized in Educational Neuroscience, we suggest Educational Psychologists as possible contenders to assume such a role as they seem to be the most skilled to lead these collaborative efforts.

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2.3 NEUROMYTHS IN EDUCATION: WHAT IS FACT AND WHAT IS FICTION FOR PORTUGUESE TEACHERS? [Study 1] *

* The following study has been published as: Rato, J.R., Abreu, A.M., and Castro-Caldas, A. (2013). Neuromyths in education: What is fact and what is fiction for Portuguese teachers? *Educational Research*, 55(4), 441-453.

Abstract

Educational Neuroscience is a relatively new discipline. However, many obstacles persist in delaying the success of an interface between Neuroscience and Education. One such major obstacle has been the spread of neuromyths (Geake 2008). The main aim of this study was to verify if Portuguese teachers are susceptible to misinterpreting neuroscientific findings and believe in neuromyths that might ultimately impair their teaching - or simply waste time investing in techniques that will not aid their students. A sample of 583 Portuguese teachers from different areas of expertise participated in this study. The participants were aged between 25 and 61 years (M=41; SD=9) and taught at Preschool to High School levels. We designed a questionnaire to assess if teachers believed in the neuromyths. Non-myth / myth statements were presented, alongside an open-ended question concerning the links between brain and education. Together, these queries afforded a database of the teachers' knowledge concerning neuroscientific facts and neuromyths. Our results suggest that teachers fail to distinguish myths from facts, irrespective of the area taught and level of teaching. However, our findings also indicate that, although teachers have difficulties in untangling myths from facts, Portuguese teachers are interested in the workings of the brain and recognise the potential of neuroscientific information in education. Results from this study suggest that communication between neuroscientists and teachers must be improved through an open, interdisciplinary dialogue. This research raises questions that should help to develop Educational Neuroscience as a discipline. Namely, we highlight the need for a translation of the educational neuroscience facts into a language shared by teachers; and the need for specific training so that teachers might make adequate use of education-related neuroscientific findings in the classroom.

Keywords: Neuromyths; educational neuroscience; teacher perceptions; brain; learning.

Introduction

Since the beginnings of neuroscience as a discipline, 'learning processes' have been a key discussion topic for neuroscientists (Meltzoff et al., 2009). However, the role of neuroscience in *educational* practice is still not clear. This may in part be due to a series of misunderstandings concerning the brain that are prevalent in the education field (Geake, 2008). Given that teachers tend to search for information to help them develop as educators, they are especially vulnerable to these misunderstandings. These misconceptions might stem from the existing gap between the different theoretical conceptualizations that are apparent in different academic fields (Samuels, 2009). Here, we aimed to assess if the neuroscientific-derived knowledge acquired by Portuguese teachers is, indeed, based on facts or fiction.

The idea that neuroscience research might influence the theories and practice of education has been around for some time (e.g., Cruickshank, 1981). However, with the advent of new technologies, the access to new scientific findings has rekindled this discussion (Varma, McCandliss, and Schwartz 2008). While some scientists argue that relating biology to education is premature (e.g., Bruer, 1997), others advocate that research in educational contexts will shape discoveries in basic biology and cognitive processes in learning and development (e.g., Fischer et al., 2007).

The debate concerning the foundations of the neuroscience-education bridge has led to an investment in the field of Educational Neuroscience and it has now been implemented as a relatively new discipline (e.g., Goswami and Szücs, 2011; McCandliss, 2010).

Nevertheless, there are still many barriers that delay progress in this new scientific field. The spread of myths that obscure the progress of cognitive neuroscience in several areas relevant to education has been one of the major problems. The misinterpretations or over-interpretations derived from studies in neuroscience have given rise to what is described in the literature as neuromyths (e.g., Della Sala, 2007).

The OECD (2002) coined the term neuromyths to refer to the common misconceptions concerning brain mechanisms. These distorted and overgeneralised ideas related to neuroscience findings are so entrenched in our society that are taken for granted.

In recent years, many of these distorted conceptions related to the functioning of the brain have been circulating in the media. Unfortunately, science blurred with speculation was unhelpful when talk of 'brain potential' appeared in non-specialist press headlines that popularized some studies of brain science. The notion of an information gap between scientists and journalists is not new (e.g., McCall, 1988), and scientists complain that press accounts of research can be oversimplified, sensationalized and inaccurate.

Previous studies have shown that public perception of research findings are generally more likely to be scientifically credible when they are accompanied by brain images or even false neuroscience explanations (Weisberg et al., 2007; McCabe and Castel, 2008).

The proliferation of myths has been related to the spread of so-called ‘brain-based learning’ programs (e.g., Geake and Cooper, 2003; Howard-Jones, 2008; Coch and Ansari, 2009). An entire industry has been established around these products. The products are heavily marketed to educational settings. For example, in the UK, teachers have received an enormous amount of e-mail propaganda encouraging them to participate in courses to learn how to use brain-training programs (Goswami, 2006). Such occurrences are global and many of the ideas spread by these commercial packages are embedded in the educational culture of schools. Portugal is no exception, and although educators show a great desire to learn more about the brain, they rarely access scientific journals and are more likely to access popular press books (Rato and Castro-Caldas, 2010). Numerous reviews explore the upsurge of neuromyths in the educational system, in several cultural contexts (e.g. Geake, 2008; Purdy, 2008). Prevalence and predictors of neuromyths among UK and Dutch teachers were also recently studied (Dekker et al., 2012). Much like in other countries, Portuguese teachers search for simplified information, invoking lack of time for scientific updates (Rato and Castro-Caldas, 2010). This is usually justified by the result of the annual placement practices (an open public contest that may imply a change of school) made by the Portuguese Government. According to Teodoro (1994), during a ten-year period, nearly 50 percent of Portuguese teachers change schools more than three times and 21.3 % change schools five times or more. This constant turnover creates instability and decreases the initiative of teachers to improve their educational strategies through field investigation. In this context, little motivation exists to affiliate with the school and its problems (DiPaola and Neves, 2009). Moreover, a political drive for investment in teacher professionalization in Portugal has led to constant performance evaluations and encouraged educators to enrol in training courses for credits (e.g., Flores and Shiroma, 2003). Due to these circumstances, necessary training might not be received. The necessary competences must then be learned elsewhere, mostly unsupervised and may be more likely to be influenced by the proliferation of neuromyths.

Neuromyths are hard to dispel because they are based on and/or may contain elements of sound science. According to a systematic review of the most popular assumptions about brain research (OECD, 2002), some of the most salient neuromyths are: i. ‘people only use 10% of the brain’; ii. ‘people are either left-brained or right-brained’; iii. ‘There are different dominant learning styles: VAK – Visual, Auditory and Kinaesthesic, and teaching using the dominant sensory modality of the learner will benefit the learning process’; iv. ‘children who drink plenty of water will improve test results due to a regularly hydrated working brain’; and v. ‘there are multiple types of intelligence and each intelligence operates from a separate area with corresponding IQs’ (e.g., Della Sala, 2007; Howard-Jones, 2010; OECD, 2007).

The idea that ‘we only use 10% of the brain’ is one of the most prevalent myths in neuroscience (Wanjek, 2002). However, science has shown that although people can live with severe brain trauma, this does not confirm the existence of ‘useless areas’ and all areas have a known function (e.g., Beyertsein, 1999; OECD, 2007).

The neuromyth ‘left-brain versus right-brain’ probably has its basis in studies of hemispheric specialization (e.g., the left hemisphere subtends language processes and the right hemisphere is implicated in spatial awareness). Hemispheric differences do exist but brain function should be considered as a whole (Geake, 2004). Neuroimaging studies have already clarified this issue by showing that both hemispheres work together and are always involved in all cognitive tasks (e.g., Goswami, 2004).

Despite the lack of scientific evidence, the educational community has been flooded with information concerning a multi-sensory model called VAK – Visual, Auditory and Kinaesthesic learning styles (Dunn, Dunn, and Price, 1984). According to this model, Visual learners learn better through pictorial information, so showing them diagrams and color images will allow for stronger memory traces due to crossed modular learning; the Auditory learners acquire knowledge by storing sounds; and Kinaesthetic learners are more successful if they do things practically, by means of movement. Strictly following a VAK regime appears to bring dilemmas for the teacher: for example, what should be done with the ‘V’ and ‘K’ learners in a music lesson? (Geake, 2008). Clearly, this it is a simplistic model and requires further research since there is no data showing an educational advantage of teaching in the preferred learning style. As pointed out by Howard-Jones (2008), neuroscience, or any other science, has, so far, not found support for the educational value of categorising learners by their sensory modality or any other type of learning style.

There is also no positive or direct evidence to link high consumption of water with enhanced learning. Drinking plenty of water has often been promoted by ‘brain-based learning' programs as a way to improve learning. It is true that dehydration can constrain brain function, reducing cognitive performance. Moderate deprivation probably produces (at least temporary) negative effects on learning. However, the myth associated with this idea overgeneralizes the aforementioned concepts: 'if a child is not thirsty and well hydrated, it would still be beneficial to encourage them to drink extra water anyway, as this will lead to better learning'. The enthusiasm for the need to consume water has been sensationalized as a supposed means to raise cognitive attainment. Ensuring that children drink 6-8 glasses of water a day to prevent brain shrinkage is not supported by neuroscience (Howard-Jones, 2009). Evidently, drinking water brings benefits to the body including its hydration, which is paramount for its proper functioning, but going beyond that would mean entering the grounds of extrapolation (e.g., Howard-Jones, 2010). Crucially, and taken to extremes, too much of a good thing can be harmful, and hyponatremia or water intoxication have been described as negative consequences of excess fluid intake (e.g., Miyamoto et al., 2012; Boetzkes, 2010; for review see Manz, 2007).

In terms of the 'Multiple Intelligences' issue, although Gardner's theory (Gardner 1993) does not find consensus among experts, most people consider that the concept of 'intelligence' entails more than one phenomenon. However, this myth is evident in the classroom as views of separate intelligences are reinforced. Teachers appear to interpret this theory as a prescription to select teaching methods depending on the type of intelligence of each student (Willingham, 2004). The best argument to resist this myth can be found in studies that show many shared and overlapping brain processing pathways between different skills (e.g., Koelsch et al., 2004).

With the Portuguese context in mind, another myth is worthy of attention. In the mid seventies, the Portuguese adopted many bio- psycho- technological crazes (e.g., Matos et al., 2006). Hence, a myth related to the exaggerated suggestion that a boost in vitamin supplement intake will stimulate the brain became prevalent in the Portuguese context. Adverts for vitamin supplements to ameliorate cognitive and physical performance, as well as attention and memory, are particularly widespread. In general, it is important to note that the speculative neuromyth ideas sometimes have true foundations, but the underlying scientific knowledge has not been widely shared across the educational community (e.g., Carew and Magsamen, 2010; Howard-Jones, 2009). The biggest problem seems to be how the information is being handled outside academic circles. It seems that the available information is manipulated to directly fit the classroom *milieu*.

Teachers are therefore likely to be exposed to these misconceptions about the brain as they seek information to improve their teaching. Here, our aim is to investigate whether Portuguese teachers are harnessing real knowledge to use in the classroom or if they are influenced by neuromyths. The study also aimed to examine a range of factors that might differentiate the teacher's adherence to neuromyths, such as their number of years of experience, their areas of expertise and the geographical region of the schools. It is hypothesised that teachers who have more experience, have natural science background and are in the main city schools would be more resistant to the acceptance of myths as facts.

Method

Participants

Participants were Portuguese teachers (from Preschool to High School). We collected data from 625 teachers. However, 42 subjects were excluded for not responding to more than half the questions of our questionnaire. Our final cohort for analysis (N=583) was composed of 438 women and 145 men, aged between 25 and 61 years (M=41; SD=9). In terms of the gender distribution, the sample comprised a high proportion of female teachers (75%), which is broadly similar to the gender distribution of teachers in Portugal as a whole. According to national data, in 2011, 77% of the teaching staff was female (DGEEC, 2013). In this study there was no significant variation in the number of correct responses between genders ($\chi^2(14) = 18.33$; p=.192).

Recruitment was carried out in 28 participating schools from nine districts of Portugal (rural and urban areas) and an Island of the Azores. Our participants' teaching experience ranged from less than one year to 38 years (M=16; SD=10) and derives from different areas of expertise such as: i) Language (N=88); ii) History (N=74); iii) Mathematics (N=106); iv) Economics (N=14); v) Biology (N=27); vi) Sports education (N=50); vii) Special education (N=18); viii) Computer science (N=21); ix) Visual arts/Music/Dance (N= 51); x) Unspecified (N=134). The unspecified area of expertise occurs because in the Portuguese education system Preschool and Primary school teachers do not usually indicate an area of expertise as they teach several areas.

Measures

We designed a questionnaire to assess the teachers' knowledge concerning the relationship between neuroscience and education. Namely, we aimed at investigating: i. If teachers were adopting brain-based techniques in their classrooms; ii. If teachers had knowledge of brain facts linked to education; and iii. Teachers'sources of information. This first group of questions was inspired by a study by Pickering and Howard-Jones (2007).

Our main analysis aimed at assessing whether teachers distinguish scientific evidence from neuromyths. Hence, in our questionnaire, we mixed the most popular neuromyths with some true scientific facts and asked the respondents to select which were myths and which were neuroscientific facts.

Except for the vitamin supplements myth, which is related to the Portuguese context, we selected the 7 non-myth/myth statements based in the OECD's Brain and Learning project (2002). Actually all the statements presented in the study have related misunderstandings. The goal was to choose only the most popular ones (the general assertions concerning the brain that are more distorted and misquoting), in this case according to OECD. However, the benefits of multilingualism and neuroplasticity were presented as facts because these subjects have been recently discussed in the media at the national level. The reason why the brain facts were not counterbalanced with the number of myths was to keep the issues in consonance with the way they were reaching (some as myths and some as facts) the Portuguese teaching community (by school newsletters). One of these neuroscientific facts considered the benefits of neuroplasticity in allowing the brain, in certain conditions, to (re)organize itself according to the information it receives (e.g., Immordino-Yang, 2007). The other brain fact opposes another well-known myth concerning multilingualism. This myth states that learning two or more languages leads to a competition for resources in the brain and that the first language should be learned 'correctly' before learning another language. Crucially, several studies have found the exact opposite effect: children who learn a foreign language in school do not evidence lower performance in their first language skills (e.g., Diamond, 2010; OECD, 2007).

Procedure

The questionnaire was administered in Portuguese. Authorization requests were sent by e-mail to 40 schools and 28 schools accepted to participate. A Researcher administered the questionnaires at the schools to the teachers that were willing to participate (most teachers were happy to answer the questionnaire and were interested in knowing more about the theme of Neuroscience and Education). First, the study would be presented in the teachers' meeting rooms. Then, the teachers who were interested in the topic were informed that they would be required to fill in an opinion survey and that they were free to leave at any time. There were no dropouts, but 42 questionnaires were not fully completed. Our survey consisted of a checklist with an additional open-ended question. A total of eight statements were presented. Teachers were instructed to classify these statements as myths, facts or otherwise indicate that they did not know whether the statement should be classified as a fact or a myth (Appendix B). The procedure for translating the questionnaire and the participants' responses fully respected all contents and was performed by a professional translator with experience in this scientific field.

Data Analysis

The data was analyzed using SPSS (Statistical Package for the Social Sciences - version 16.0 for Windows). The questionnaire was analyzed as follows. In the set of queries with closed responses, the items were rated concerning the option selected (e.g., yes or no; myth or fact). Percentages of each type of answer were computed. Finally, correlation analyses were performed for the percentage of correct answers on the non-myth/myth statements and the area of expertise of teachers, school type (primary/high school), years of experience and geographical region of the school. The answers to the open-ended question were coded into thematic units (e.g., learning disabilities; multi-sensory educational styles) through a content analysis according to the number of occurrences. This open-ended question requested teachers to describe their (concrete) ideas concerning how the brain is linked to education. With this question, we intended to assess the existence of any notions that would give further support to the possible misclassification of the non-myth / myth statements.

Results

In total, 219 of 583 participants (37%) replied to the open-ended question inquiring about their knowledge concerning how the brain might be linked to education. Of these, 32% (N=69) responded using references to neuromyths and not to neuroscientific facts. The misconceptions mentioned by teachers, concerned: i. educational strategies for multiple intelligences (60%); ii. differences between male and female brains (6%); iii. vitamin supplements that improve learning (17%); iv. exercising the brain/brain gym (7%); v. hemispheric differences (4%); vi. multi-sensory educational styles (6%). Most teachers listed no more than two ideas.

Moreover, 63 teachers (29%) suggested that there is no learning without the brain and mentioned the benefits of 'neuroeducation'. Learning needs and conditions such as dyslexia and ADHD were mentioned by 28 teachers (13%). Additionally, we found references related to the memorization process (n=27; 12%) and to good sleep habits as essential for brain health (n=4; 2%). The remaining answers were other ideas that did not fit into the groupings (6%). 14 teachers (6%) stated "I do not remember anything right now".

In terms of the sources of information used by teachers, television was selected 444 times (23%) and the Internet 390 times (21%). These stood out as the main sources of information. Books and scientific journals also appeared as important resources for teachers, chosen 353 (19%) and 329 (17%) times, respectively. In the open-ended option, 'others', 37 teachers (2%) indicated 'other professionals' as a common source of information (see Figure 1).

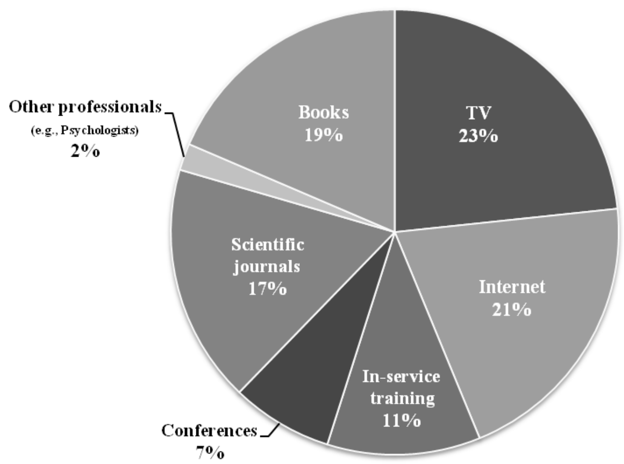

Figure 1. Main information sources selected by teachers.

In terms of the use of brain-based techniques, our data showed that 71% (N=416) of the teachers do not adopt techniques based on ideas concerning the brain and 11% (N=64) ignore the existence of these techniques. The 103 teachers (18%) who indicated the use of these techniques in their classrooms, characterized them as: i) strategies for memorization (19%; N=20); ii) methods that follow the multiple intelligences perspective (16%; N=17); and iii) multisensory exercises (4%; N=4). The other techniques reported by teachers were unclear and unrelated to what was asked (e.g., creative learning, use of audio-visual and computers, brainstorming, strategies applied in special education). Moreover, 35 teachers (34%) did not refer to any type of technique.

In order to investigate possible factors that might have contributed to the existence of difficulties in sorting neuroscientific facts from myths, we grouped teachers by: i. Area of expertise; ii. Educational stage of their students; iii. Years of experience; and iv. Geographical region where teaching took place. We analyzed the average percentages of correct recognition of myths/facts. However, and crucially, the identification of myths and facts by our teachers grouped by any of these variables did not show any significant relationship ($p>0.05$) given by Pearson Chi-Square tests: Area of expertise x correct identification ($\chi^2(35) = 32.83$, $p = .573$); Educational stage x correct identification ($\chi^2 (28) = 21.77$, $p = .792$); Years of experience x correct identification ($\chi^2 (14) = 15.58$, $p = .340$); and Geographical regions of teaching x correct identification ($\chi^2 (21) = 11.07$, $p = .961$). All the groups were then thus treated as a unit since there were no significant variations in the number of correct responses between them.

Of the six neuromyths and two brain facts presented to teachers, two of the myths were considered as facts by more than 50% of teachers. Percentages of correct (myth recognized as myth and fact recognized as fact), incorrect (myth recognized as fact and fact recognized as myth) and the uncertain (‘I don’t know’) responses are depicted in Figure 2.

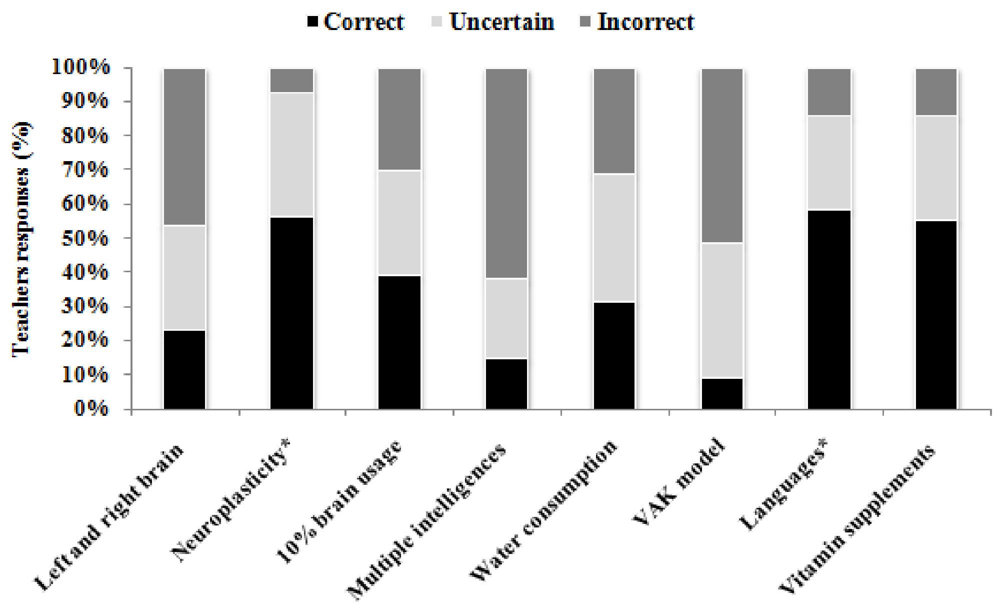

Figure 2. Percentages of uncertain, correct, and incorrect responses.

Discussion

The present study explored Portuguese teachers' knowledge about neuromyths. The teachers' views on the relationship between neuroscience and education have already been studied (e.g., Howard-Jones et al., 2009; Pickering and Howard-Jones, 2007). Recent studies used online surveys (although, this research method does not control for online research of the answers) to assess teachers' perceived importance of neuroeducation in the United States (Serpati and Loughan, 2012) and general knowledge of the brain/neuromyths in samples from the United Kingdom and the Netherlands (Dekker et al., 2012), indicating a cross cutting concern from different cultures.

Our open-ended question revealed that the Portuguese teachers in our study showed some interest in the workings of the brain and recognized the potential of neuroscientific information in education. However, results suggest a gap between their interest and proficiency in the use and interpretation of scientific information.

Our study highlights the difficulty of distinguishing myths from facts in this context. The myths 'multiple intelligences', 'preferred learning style (VAK model)' and 'left-brain versus right-brain' were the most prevalent. Less than 20% of the teachers identified these myths. The myth concerning the use of different educational strategies for each type of intelligence was the one that revealed most misinformation among Portuguese teachers. This neuromyth was also referred to the most in the open-ended question. Pickering and Howard-Jones (2007) also noted this trend, as the teachers in their interviews often mentioned the usefulness of strategies for emotional intelligence. Even the author of this theory (Gardner, 1993) recommended that it should not be mistaken for a prescription for schooling; it seems that teachers still associate the concept of Multiple Intelligences with neuroscience and use it as a guide for understanding different learning styles. Clearly, it is important that the educational community is aware of this false interpretation. A more accepted view is that each person has a general intelligence. As Willingham points out "the vast majority regard intelligence not as a single unified entity, but as a multifaceted phenomenon with a hierarchical structure" (2004, 19).

According to the teachers' responses, the multi-sensory learning style constitutes another myth present in the school community. This may be related to some intervention programs that have recently appeared in Portugal to promote certain educational strategies with children. Evidence pertaining to this is still inconclusive. It should be clarified that identifying a learning style preference does not necessarily mean that a particular student will automatically operate in this way across all areas of learning, nor that it is more beneficial to adapt the learning style to the student in detriment of the contents to be taught.

Even the two brain facts presented led teachers astray. Almost 40% of the teachers were uncertain that learning relied on synaptic plasticity. It is possible that this uncertainty is revealing of a knowledge concerning the existence of the concept of plasticity but an absence of knowledge concerning how plasticity processes occur.

In Portugal, brain-based training programs for teachers are very recent and are not widely spread, as it occurs, for example, in the UK (Goswami, 2006). Accordingly, participants in this study were asked if they made use of this type of technique and what were their strategies (but not if they participated in these training programms). Their responses revealed poor knowledge of brain-based techniques, which suggests they do not use them.

This study suggests that the difficulty of distinguishing myth from fact is apparent across different areas of teaching, expertise and grade of education. The lack of significant differences in our analysis has shown that Biology or Computer science teachers fail to recognize a myth from a fact just as much as a Languages or PE teacher. Moreover, High School teachers succumb to these same myths just as much as Preschool teachers. It seems that the number of years in training or the similarities between the area of expertise of the teachers and the origin of the myths are not of consequence, in this study at least. This observation is in agreement with the Dutch study (Dekker et al., 2012) since the teachers' level of knowledge did not suffice to allow for the recognition of the difference between brain facts and brain myths. Furthermore, teachers from main city schools are not more resistant to the acceptance of myths when compared to teachers from small school settings in the interior of the country. Lack of information might have led Portuguese teachers to avoid responding the open-ended question concerning the role of the brain in education. Additionally, the minority that did respond to this question referenced some common neuromyths. These findings predominately support the idea expressed by several neuroscientists (e.g., Fischer et al., 2010; Howard-Jones, 2010): caution is needed in the vocabulary used and the scientific information must be easily accessible to teachers. Cultural variations and possible historical differences in the public education systems have led Portuguese teachers to want to understand international scientific progress. Crucially, teachers have realized that they cannot ignore the brain issues in education (Rato, Abreu and Castro-Caldas, 2011). However, although teachers are attracted to how the brain works, they have difficulties in transferring the existing neuroscientific findings to educational practice. Their misconceptions might stem from the sources Portuguese teachers seek to obtain information from, since the media (television and internet) seem to be the most consulted resources. Teachers rarely access scientific journals, and we wonder if the scientific language of relevant journals is sufficiently accessible to be useful to teachers. We agree with Carew and Magsamen (2010) when they suggest that journalists, teachers and parents need to discuss neuroscientific topics together to better understand what is and is not accurate.

Thus, even if teachers are not completely familiar with all neuroscientific concepts, for these to serve as guidelines for teaching, they can, at any rate, use their knowledge to prevent teaching errors. In this sense, some basic knowledge of Neuroscience is useful for teachers to avoid the propagation of myths. In this sense, we agree with Dekker et al. (2012) in recommending the incorporation of neuroscience courses into initial teacher training programs, since some basic knowledge of neuroscience is useful for teachers to avoid the propagation of myths.

However, increasing communication between neuroscientists and educators seems to be crucial for the empowerment of teachers through the creation of a new transdisciplinary scientific field. It is particularly necessary to translate educational neuroscience facts for teachers and provide training with respect to how teachers might make use of education related neuroscientific findings in the classroom. While there are still few professionals specialized in Educational Neuroscience, we think that Educational Psychologists are able to assume this role (Rato, Abreu, and Castro-Caldas, 2011).

In order that Educational Neuroscience might develop, we must move beyond unfounded myths to establish the neuroscience-education bridge. Recently, promising signs have begun to emerge, such as: the creation of *neuroschools* that aim to provide an international platform to foster societal awareness and transdisciplinary collaborations in neuroscience (Frazzetto, 2011; Goldin et al., 2013); and the appearance of conferences such as those from the European Association for Research on Learning and Instruction (EARLI SIG22 -Neuroscience and Education; http://www.earli.org/) that contribute to the international discussion concerning the field of educational neuroscience.

This study has suggested that teachers do not find it easy to distinguish between scientific facts and neuromyths. This corroborates the concerns launched by OECD (2002) and other authors (e.g., Geake, 2008; Goswami, 2006) about the spreading of neuromyths in the educational community. It is important, therefore, to support a translational process to provide opportunities for teachers and neuroscientists to collaborate.

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3 THE CONTRIBUTION OF NEUROPSYCHOLOGICAL ASSESSMENT TO THE SCREENING OF EMERGENT MATH SKILLS

3.1 EMERGENT MATH SKILLS: A PROPOSAL FOR A PROTOCOL OF NEUROPSYCHOLOGICAL ASSESSMENT FOR PRESCHOOL-AGED CHILDREN *

***** The following review is adapted from: Rato, J.R., and Castro-Caldas, A. (2010). Competências matemáticas emergentes: Avaliação neuropsicológica de crianças em idade pré-escolar. In C. Nogueira, I. Silva, L. Lima, A. T. Almeida, R. Cabecinhas, R. Gomes, C. Machado, A. Maia, A. Sampaio & M. C. Taveira (Eds.) *Actas do VII Simpósio Nacional de Investigação em Psicologia* (pp. 607-625).

Abstract

There is a growing interest of neuropsychology in the cognitive processes that children use during their learning. Currently, it is necessary to define a profile, determined by neuropsychological assessment, for analysing early forms of learning. The present work involves the organization of a neuropsychological assessment protocol in order to obtain tools in Portuguese language that can be used in clinical and educational contexts, for screening of children from 3 to 5 years. This protocol will focus on the study of: 1) neuropsychological areas associated with emerging mathematical skills, i.e., visual-spatial abilities, finger gnosis and executive functions; and 2) the numerical skills (symbolic and non-symbolic). More specifically, this work seeks to review the components that support the processing and numerical representation of preschoolers. Then a neuropsychological assessment protocol is proposed to analyse these components, and verify its weight to number sense, as the perception of small quantities (subitizing) or the ability to use fingers functionally and represent them mentally.

Keywords: Neuropsychological assessment, number sense, subitizing, preschoolers.

Introduction

In the last few years the interest on childhood neuropsychology in scholastic extent increased (Hale and Fiorello, 2004; Lussier and Flessas, 2001). Many are the neuropsychological disruptions spotlighted in this context. At the beginning of the 90´s Obrzut and Boliek (1991) ascertained that 10-15% of children and youngsters showed learning difficulties due to brain injury or brain disturbance. Nowadays, in other countries, pre-school learning difficulties have demonstrated to be one of the most required sectors in neuropsychological evaluation (D´Amato, Fletcher-Janzen and Reynolds, 2005).

Neuropsychological evaluation has been recognized as vital to define diagnostics (Lezak, 2003), since this procedure enables analysing children's conditions with development changes in a more trustworthy way, as well as its difficulties and capabilities. Studies carried out so far with the aid of neuropsychology, have significantly changed the way of understanding certain learning problems, as it is the case of dyslexia (Shaywitz et al., 2001).

Yet, and contrary to what happens with linguistic skills, logical-mathematical reasoning is still not contemplated in the majority of neuropsychological assessment batteries. This means that there is still a lot of work to be done towards the upgrading of assessment resources.

Nowadays, the study of mathematics on brain is the area that is most intriguing to scientists. Therefore, a significant increase in neuroscientific literature is expected in the near future (Dehaene, 2009).

Despite being quite ancient, Mathematics is a basic requirement for any citizen and it is a demand of the 21^{st} century society. Although inserted in a social context immersed in numbers and statistics, many literate citizens remain mathematically dysfunctional.

OECD reports (2006) have presented worrying facts related to national indicators of scholastic success/failure at basic and secondary education. Portuguese students are commonly classified by possessing low academic skills, especially at mathematics, when compared to their European peers.

As a matter of fact, and to worsen this scenario, most people that assume a low linguistic level can turn daily activities even more difficult in adulthood. Frequently, numeracy (this is, being able to deal with numbers, quantities, estimations, calculations) is assumed to be less important than literacy. However, Parsons and Bynner (2005) demonstrated that math skills have great expression in our daily life influencing academic courses and less qualified professional areas. Mathematics is essential either in relation to the simple things in daily life, like going shopping, or to great scientific discoveries in several areas, such as technology (Cantlon, Platt and Brannon, 2009).

Therefore, mathematical skills are very important to the development and progress of our society but, when compared with literacy, little is known about the components that support these abilities.

In this essay we carry out a brief revision of the main theoretical models behind early math skills. Also, our study object concerns neuropsychological tasks published in the last years directed to children in pre-school age. At the end of this revision we will present our proposal for a neuropsychological assessment protocol on math skills directed to preschool-aged children.

Brain and mathematics: Models and current questions

When does numeracy arise in our mind? How do math skills develop? Is there a specific region in our brain dedicated to logical-mathematical reasoning? Is only humankind able to understand and use mathematics? These are some of the questions whose answers are still in discussion.

Supporting some studies it looks like there is a biological primary system to understand the inner understanding of numbers and can be observed early on since we are babies (Geary, 1995). Some authors claim that when babies are born they already discriminate quantities (Xu and Carey, 1996; Xu and Spelke, 2000). Experiments with animals mainly with primates and birds show that these also recognize different quantities and can make small numeric calculations (Cantlon and Brannon, 2007, Brannon et al., 2001). This information seems to indicate that perception of quantities and simple data processing are universal features which evolved millions of years ago and make part of a common ancestor past at least to birds and mammals.

Piaget's error and recent neuropsychological models

It is indubitable that Jean Piaget´s theory of cognitive development (1970) was crucial to understand children´s behaviour and still represents today a determinant theoretical reference to Educational Sciences and Behaviour. Even so, experts on the area of education have already admitted that the principles underlying to Piaget´s theory although having some limitations were also wrongly interpreted. As a result, there was an overly literal and strict application to educational practice (Sequeira, 1990).

Despite being well-known all over the world, there have emerged alternative conceptions in what concerns the contribution of this theory from which it is possible to underline those which refer to the development of logical mathematical reasoning.

According to Piaget, children aged less than four years old do not develop any kind of numeric meaning. Other authors agree that Piaget´s error was mainly due to the way mathematical concepts were tested. The use of explicit questions and the exclusive analysis of verbal answers of children in their experiments (ex. Numerical conservation test) enabled Piaget to identify real skills of children aged between three and five (Blakeore and Frith, 2009; Dehaene, 1998).

Wynn (1990; 1992; 1998) was one of the first researchers to hold alternative experiments to Piaget´s whose results went against his theory revealing that the inner knowledge of young children had been neglected.

Butterworth (1999) and Dehaene (1997) are the authors of two of the most discussed books and who also are relevant references in this area of study. Their perspective is not in agreement I what concerns the innate capacity to of Mathematics. Dehaene (1997) stands for the idea that each person owns since early times a kind of accumulator which enables him/her to follow quantities of various dimensions although only recognizes with more precision small amount of objects. Butterworth (1999) makes a previous reference to a Module of a number defining it as a capacity to acknowledge cardinals without having to turn to counting and outlines the skill of using fingers and having them mentally represented as a buttress of our numerical processing and representation.

Dehaene (1997) was the biggest impeller of the `sense of the number´ defining it has a universal ability respecting representation and manipulation of non-verbal magnitude spatially oriented in a `mental numerical line´. This author also elaborated the most mentioned numerical representation model in literature known as the triple code (Dehaene, 1992). On the basis of this model, all the numeric information can be manipulated on the brain in three ways: Arabic-visual, verbal and analogical. In analogical representation of quantity, numbers can be enacted in verbal format/structure (ex. twelve) and a visual way in which the number is shown as a sequence of numerical symbols (ex. 12). This process permits the information to be modified from one code to another, this is, to commute an Arabic number to a numerical word (1 to one) and vice-versa (Castro-Caldas, 2006).

Recently, Krajewski (2008) suggested a precocious mathematical development model in which he estimates that the emerging skill of quantity is obtainable through three stages which lead the child towards a bigger understanding of quantity to the connection of word-number (Krajewski and Schneider, 2009). This model entails that children make a process transition to a more and more conceptual understanding of numeric words. Although these assumptions seem reasonable, many questions about the stages of numeric cognitive development are still waiting for an answer.

Neuropsychological evaluation and mathematical skills

By means of recent imaging techniques it has become possible to observe different brain areas which become active when solving logical numeric and calculation problems. Some studies suggest numerical calculation skill is located on the parietal lobe of the left hemisphere. Dehaene and collaborators (2004) indicated that the sense of number depends basically on parietal and pre-frontal areas with the horizontal segment of the intra parietal bilateral area. However, according to other studies, it seems there is a bigger distribution of brain activity being easier to locate a specific area for mathematical reasoning (Varma and Schwartz, 2008). The fact of distinct type of assignments like addition, subtraction, comparison and multiplication activate different brain regions could be the cause of many uncertainties. Yet it is natural that many doubts prevail as the scanning of these skills is a long and lasting process given its structure complexity and multiple functioning interactions of the brain (Dehaene et al., 1999).

In neuropsychology both national and international literature traditionally accosts researches about the performance of adults with brain damage in tasks which essentially assess cognitive and communicative processing. It all happens in such way that there are few studies about population under development existing great scarcity of information to neuropsychological evaluation in several domains.

What do neuropsychological batteries evaluate for pre-school children?

It is known that brain development presents particular characteristics according to each age stage and development factor is considered one of the biggest obstacles when speaking about batteries standardization tests for children (Rey-Casserly, 1999).

At present pre-school assessment of children constitutes a dilemma to the majority of neuropsychologists due to the narrow amount of standardized measures with formal information which work in a consistent way during a period of deep neurodevelopment change as the one occurring in our first years of life (Heffelfinger and Koop, 2009).

Even in the international scene, there are few neuropsychological evaluation batteries for pre-school children as the most well-known are *Kaufman Assessment*

Battery for Children (Kaufman and Kaufman, 1983), *Wechsler Preschool and Primary Scale of Intelligence – WPPSI-III* (Wechsler, 1989) and *Woodcock-Johnson III Tests of Cognitive Abilities* (Woodcock, McGrew & Mather, 2006).

The NEPSY – *Developmental Neuropsychological Assessment – Memory and Learning Domain* (Korkman, Kirk and Kemp, 1998) is the neuropsychological battery to assess children aged 3 to 12 years old that has most detached internationally being adopted by eight countries excluding Portugal (Korkman, 2001).

Heffelfinger and Koop (2009) defend that the majority of children in pre-school age with evident need of a neuropsychological assessment are not examined until they reach school age. This restraint on assessments limits the precocious intervention and can lead to a less effective rehab on certain neuropsychological functions (Johnson, 2005).

All neuropsychological assessment must have a balance of intellectual, verbal, non-verbal functions to establish an inter and intra individual standardized comparison to guide hypothesis of dysfunction and selection of complementary tests to accomplish a differential diagnostic (Lezak, Howieson and Loring, 2004). Nevertheless, we ascertain that the existing neuropsychological assessment batteries have not inserted numeric skills in its amount of subtests and performance levels to evaluate.

We defend that apart from the most investigated areas such as amnesic, linguistic, praxic and executive functions it is also relevant to explore other neuropsychological domains as it is the case of logical mathematical functions. As a priority it urges to investigate how these logical mathematical functions are correlated with the others.

How can neuropsychological tests be used to measure Maths skills on children?

Before school age, society promotes some skills which precede symbology teaching namely those of verbal mediation to the quantity understanding and counting operations also establishing a connection with body elements (counting using fingers) or external to it (objects) (for review see Castro Caldas, 2006). According to recent studies, body elements like finger gnosia are good predictors of children´s performance at Math’s (Penner-Wilger et al., 2008; Penner-Wilger et al., 2007).

Noël (2005) wrote on his study that enforced neuropsychological tasks, contrary to the general measures of cognitive development, permitted the identification the predictive power of representation of fingers in numerical skills on literate children.

Neuropsychological tasks assume to be fundamental to further studies on mathematical skills.

Visual-spatial skills, executive functions and quantity perception (*subitizing*) are examples of the latest neuropsychological tasks been tested (Rips, Bloomfield and Asmuth, 2008; Cordes and Gelman, 2005). These areas have evidenced significant associations with some maths skills but it is not yet clear its foretelling levels. However, the integrated analysis of a set of neuropsychological functions with the emerging maths skills still needs to be explored.

Pre-school Neuropsychological Assessment Battery of Lisbon – *BANPEL*

Recognition of the need for a neuropsychological evaluation pre-school has increased (Rey-Casserly, 1999; Heffelfinger & Koop, 2009). However, currently, there is a significant lack of standardized assessment tools for various neuropsychological domains.

The Pre-school Neuropsychological Assessment Battery of Lisbon – *BANPEL* (*Bateria de Avaliação Neuropsicológica Pré-Escolar de Lisboa*) appears to bridge the so mentioned gap and it was first suggested on the research project of Rato (2009) financed by Foundation for Science and Technology (FCT). This work follows the line of the Cognitive Neuroscience Investigation Group (GNC) from the Institute of Health Sciences of Catholic University of Portugal led by Professor Alexandre Castro Caldas. *BANPEL* focuses on the neuropsychological assessment of emerging mathematical skills which is responsible for: 1) neuropsychological areas associated to emerging mathematical skills like attention, visual-spatial skills, mnesic processes and executive functions; 2) numerical skills (symbolic and non-symbolic) according to age, gender and social and cultural factors.

The neuropsychological assessment protocol that we propose assumes a unique position, because wants to explore the emergence of mathematical skills through the development and selection of tasks that assess this educational area and neuropsychological functions associated with it. Many theoretical models being discussed at present under child neuropsychological subject are being considered in order to build and select tests to use (e.g., Kaufmann and Dowker, 2009; Bisanz et al., 2005) as other international neuropsychological tasks already published (e.g., Espy, 1997; Korkman, Kirk and Kemp, 1998). Recent empiric studies were also examined and these analyze mathematical skills under the neuropsychological perspective (e.g., Penner-Wilger et al., 2008; Bull et al., 2008; Anderson and Penner-Wilger, 2007; Kroesbergen et al., 2007; Espy et al., 2004).

Most of the tasks of our protocol is in computerized format and are presented to children as a game. We devised “Help Henry!" (in Portuguese, “Ajuda o Henrique!”) for this purpose and all the instructions are framed in the history of the game: The Henry boy, who entered in a maze and now can’t find the exit without help. The children are encouraged to do the several tasks in order to help Henry getting out of the maze (Figure 1). We used SuperLab 4.0 for computer based tasks. In our protocol there are also tasks that are not computer based, in this case the instruction came from the experimenter but always linked with the game ‘Help Henry!’.

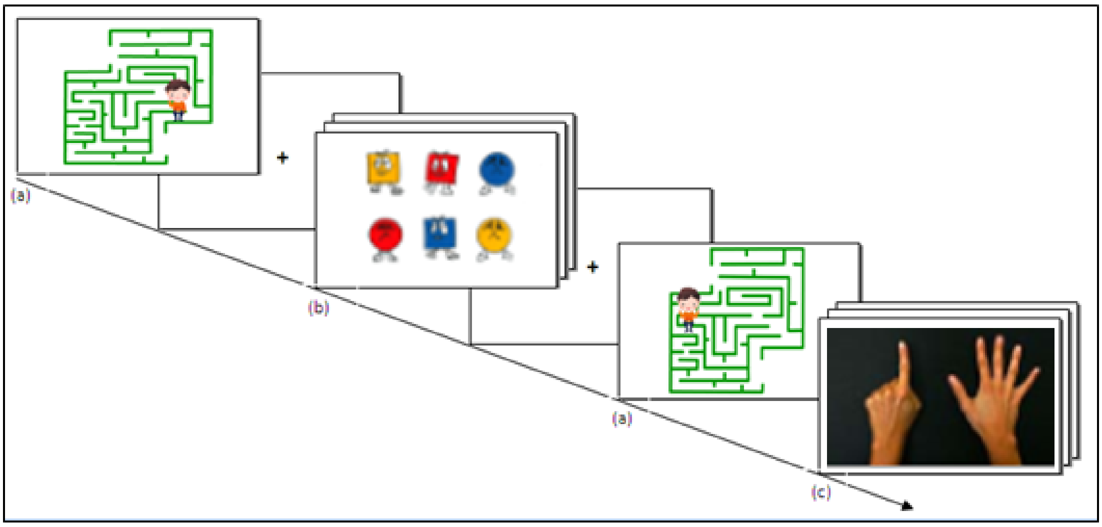

Figure 1: Schematic view of the three computerized tasks.
(a) Game instructions ‘Help Henry!’, (b) Task ‘The Shape School’, (c) Task ‘How many fingers?’.

The neuropsychological assessment protocol here proposed has the following domains of analysis: i) executive functions; ii) visual-spatial working memory; iii) finger sense; iv) emergent math skills (subitizing and the number knowledge).

i) Executive Functions (EF)

Evidence concerning the great influence of executive functions (EF) upon the process of learning during childhood (Clair-Thomson et al., 2006; Bull and Scerif,

2001) has been related to emerging mathematical abilities (Espy, 2004; Bull and Espy, 2006). The evaluation of EF aims to check the adequate use of task resolution strategies to get a goal. This capacity includes planning, impulse control and active memory search processes implying thinking and (re)acting flexibility (Bull, Espy and Wiebe, 2008; Bull et al., 1999). To assess this domain we selected *The Shape School* test (Epsy, 1997), over which we have an agreement of use with the author. This measure uses a colourful short story book format and it was drawn to analyse, mainly, inhibition and flexibility processes.

ii) Visual-Spatial Working Memory (VSWM)

Following latest research, precocious spatial sense has expressed a key factor to the development of the sense of number (Van Nes and De Lange, 2007). After showing the significant connection between visual-spatial memory and arithmetical performance (e.g., Bannoff, 2006), we consider to assess this skill on pre-school children as well. On our protocol we chose the classic neuropsychological task I this area. The *Corsi Block-Tapping Task*, originally developed by Corsi (1972), enables the assessment of visual-spatial working memory in a short time period through sequences of blocks. It is used for decades, either in clinical context or research itself (Pagulayan et al., 2006; Hamilton et al., 2003).

iii) Finger sense (finger counting and finger gnosis)

Preliminary but compatible studies defend that finger gnosis and its use seem to be related with calculation mastery of children in their first years at school (e.g., Gracia-Bafalluy and Noël, 2008; Penner-Wilger et al., 2008). Two tasks were designed to assess the finger counting and finger gnosis, the *Which finger?* and *How many fingers?*. Our tasks are inspired on one designed by Fayol, Barrouillet and Marrinthe (1998) and Noël (2005) having some elements added. With the task *Which finger?* we assess trough the touch component (isolated, successive and simultaneous touch). Here the child's hand is covered with a box and the other side the experimenter touches one or more fingers and asks: "*Show me the finger(s) that I touched*". With the task entitled *How many fingers?* the child is asked to tell the quantity seen on the pictures. On the computer screen, photographics of hands are shown with typical counting format.

iv) Emergent mathematical skills

(non-symbolic tasks -*subitizing*)

The quick perception of small amounts without having to count (*subitizing*) has been pointed as a relevant variable factor to trace learning difficulties concerning mathematic (Desoete et al., 2009). For this purpose was developed the non-figurative task *Where are more dots?* in which different set of dots are shown and from where the child identifies which amount carries the biggest quantity in a short period of time (to avoid the counting procedure). The building of this task follows several studies (e.g., Shinskey et al., 2009; Plaisier et al., 2009; Barth et al., 2005).

(symbolic tasks –number knowledge)

Many authors underline the vital role that count skills have on arithmetic development (Le Corre et al., 2006; Van de Rij and Van Luit, 1999). It is obvious emerging mathematics involves process of counting (Ansari et al., 2003; Wynn, 1990) in that the ability to count bridges the meaning of numbers and more complex arithmetic skills (Butterworth, 2004; Sarnecka and Carey, 2008).

In our protocol the symbolic tasks assess the number knowledge (for instance, indicating which of the numbers is higher or lower).

Conclusions

The lack of specific and standard measurement instruments for research with children has become the utmost fault on national neuroscientific research (Simões and Castro Caldas, 2003). However, the brief revision of this essay allowed the identification of shortage of tasks oriented to neuropsychological assessment of pre-school children, in general, and mathematical skills, in particular, not only in our national context but also on an international context. Was this scarcity of neuropsychological assess tools to preschool population that justified the need to develop *BANPEL*, which is ceils both relevant sides. On one hand, it suggests the cluster of instruments which after being tested will be used in neuropsychological assessment. On the other hand, it contributes to an improved understanding and characterization of emerging mathematical skills of preschool children.

We consider a specific protocol for neuropsychological assessment from which we believe it is feasible to obtain an adequate profile that represents the base for recommendations to precociously help children having problems or are likely to develop learning difficulties in mathematics.

As a result, the set of tasks defines our first step to reach possible instruments which can be used in clinical and also educational pre-school contexts. A neuropsychological pre analysis done on time can be important to set, for instance, methodologies and teaching strategies to each children´s specific profile considering them as eventual disturbances or shortcomings.

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3.2 PORTUGUESE ADAPTATION OF *THE SHAPE SCHOOL* TEST FOR APPLICATION IN RESEARCH AND NEUROPSYCHOLOGICAL ASSESSMENT*

***** The following paper has been submitted to publication as: Rato, J.R. and Castro-Caldas, A. (*submitted*). Portuguese adaptation of *The Shape School* test for application in research and neuropsychological assessment. Cadernos de Saúde

Abstract

The Shape School (Espy, 1997) is a neuropsychological test of executive functions for preschool-aged children. The lack of Portuguese measurement tools to assess this domain has been reported. This study aimed at adapting the use of *The Shape School* for Portuguese speaking subjects. The adapted version was back-translated and reviewed by a team of specialists. A sample of 137 children was collected so far. The age range analysed was from 3 to 5 years (M=60; SD=9; in months). According with our preliminary results, the adapted version was appropriate to obtain the discrimination among children of different preschool-ages. Therefore, the Portuguese version of *The Shape School* was considered suitable for research and clinical purposes.

Keywords: Executive functions, neuropsychological test, preschool children, Portuguese adaptation.

Introduction

Ten years ago, the lack of neuropsychological assessment instruments adapted to Portuguese was reported (Simões and Castro-Caldas, 2003; Simões et al., 2003). Presently, this is still a national demand. The child neuropsychology field is a relatively new area in Portugal, with few centres of research. Specialized training is also recent and, currently, we have the first graduate students completing their master or doctoral training programs in this scientific domain.

Child neuropsychology has their study focus on the child brain-behaviour relationship, and neuropsychological testing is one of the tools used for this purpose (Spreen and Strauss, 1998). It is precisely this attempt to understand a child's behavioural and psychological functioning in terms of brain-behaviour relationships that distinguish neuropsychological assessment from other forms of assessment (Lezak, 2003).

Neuropsychology evaluation has become an essential tool in diagnosis, mainly because it is based on the exploration and analysis of a broad range of functions, as sensory-perceptual, attention, language, memory, among others (Baron, 2004). A principal goal of a neuropsychological assessment is to determine the extent to which a child's possible difficulties in, for example, thinking, talking, learning, or even in emotional or behavioural disturbances, may form a pattern of impairment related to central nervous system dysfunction (Black and Stefanatos, 2000).

The development of sophisticated neuropsychological testing techniques have led to increased interest in the role of cortical regions, particularly the frontal lobes, to which neuropsychology call “executive function(s)” (Carpenter et al., 2000).

Executive functions (EF) imply the monitoring and self-regulation of thought and action, the ability to plan behaviour and inhibit inappropriate responses (Goswami, 2008). The executive functioning has been studied by neuropsychological theories in the last few decades (e.g., Miyake et al., 2000). However, these studies have been done mostly with adults and less with children. The measurement of this cognitive domain in preschool-aged children have found some difficulties in the past (Hughes and Graham, 2002) and only increased in recent years (Anderson and Reidy, 2012).

The contrasting views’ regarding the concept of EF and their components is often related to the specific field of study (e.g., educational psychology, neuropsychology). The EF definition most quoted was the “central executive” by Baddeley and Hitch (1994). However, Luria (1966) was pioneering when proposed a four-component EF model, which was composed by: 1) anticipation, 2) planning, 3) execution and 4) self-monitoring. Luria described individuals with executive functioning problems as demonstrating a disconnection between “knowing” and “doing” (Purdy, 2011). Years later, Lezak (1995) followed Luria’s model and conceptualized his model as also having four components: 1) volition (including self-awareness and self-monitoring), 2) planning, 3) purposive action, and 4) effective performance. According to Lezak et al. (2004) these behaviours are all necessary for appropriate, socially responsible and effectively self-serving, adult conduct.

Whether EF should be considered unitary (a single, general construct with multiple interrelated subprocesses) or non-unitary (a collection of dissociable or independent processes) is still under debate (Jurado and Rosselli, 2007). On the other hand, fields as developmental and cognitive psychology, view executive functioning as part of the metacognitive system, rather than part of a hierarchy (Roebers et al., 2012). This “thinking about thinking” is connected with the individual ability to observe and assess more basic cognitive processes and includes self-awareness, self-monitoring and self-control of cognition while performing an activity (Kennedy and Coelho, 2005).

Despite a precise definition of EF remains elusive, there is a relative agreement that it is a complex set of processes that is responsible for goal-directed behaviour, such as planning, cognitive flexibility, inhibition, organization and working memory (Natale et al., 2008; Chan et al., 2008). As the definition implies, these components are particularly critical when solving novel problems.

According to several authors, EF seem to improve sequentially through childhood. The development of EF is significant during the early years, particularly between 3 and 5 years-old (Senn et al., 2004; Wiebe et al., 2011). The EF has been strongly associated with the prefrontal cortex, one of the areas of the brain that develops more slowly (Espy et al, 2002; Wiebe, Espy, and Charak, 2007). During preschool period, the development of the core components of the EF will be the foundation defining how it will develop higher cognitive processes in adulthood (Garon et al., 2008).

As Zelazo et al. (2004) point out, preschoolers have the capacity of thinking about the past and planning for the future, as well as representing multiple aspects of a problem and choosing the best alternative of action. The ability to inhibit overlearned behaviour was identified as the first EF to emerge in children (child's first year), and this seems to allow them to increase attentional control over the environment (Davidson et al., 2006). The ability to inhibit task-irrelevant information, on the other hand, shows its greatest development later, between the ages of 6 and 10. Other executive skills such as planning (ability to identify and organize the steps and elements needed to achieve a goal), set-shifting (the ability to switch rapidly between different response sets) and the ability to maintain information in working memory, seem to develops in children between 3 and 5, with significant improvement after age of 7 (Anderson, 2002; Carlson, 2005).

The EF important role in learning during childhood and its implication in school achievement has already been demonstrated (Monette, Bigras, and Guay, 2011; St Clair-Thompson and Gathercole, 2006). Children's ability to control attention and action were considered stronger predictors of academic performance than is IQ or entry-level maths or reading skills (Blair, 2003).

Therefore, there are good reasons to focus EF assessment on preschoolers (Best, Miller, and Jones, 2009; Espy, 2001).

Considering the need and importance of studies on EF in preschool it is surprising that there are no studies of standardisation of this stimulus in Portugal. To fulfil this gap, the present research proposes an adaptation of *The Shape School* test to be applied in Portuguese speaking subjects.

Method

Participants

One hundred thirty-seven students (*N*=137) were collected from 4 preschools around the city of Lisbon (Portugal) with ages between 3 to 5 years (M=60; SD=9; in months). In total, 57% (*n*=78) are boys. Regarding the distribution by group age, 14% has 3 years, 31% has 4 years and 55% has 5 years (Table 1). All children were Caucasian and native Portuguese speakers. According to their teachers (and confirmed by parents), no child had known learning disabilities or others developmental disorders. Sixty-one percent (*n*=84) of the participants' parents provided education level information, of these, 57% hold university degrees and 39% held post-graduate degrees.

There were no differences between the group ages in the proportion of boys and girls ($\chi^2(2) = 2.15$, $p = .341$) or parents educational level ($\chi^2(10) = 17.84$, $p = .058$).

Table 1. Description of participants (*N*=137)

		Age*		Sex	
Group	*n*	Mean	Range	Male	Female
3 years	20	44	40-47	10	10
4 years	42	55	49-59	21	21
5 years	75	68	60-71	47	28

Note: *In months.

Measures

We used *The Shape School* test, originally designed by Espy (1997) for use with children aged 3 to 6 years. This test follows a storybook format depicting different colored (red, blue, yellow) cartoon shape figures (squares and circles) that are assuming the role of students attending a school. The story begins by setting up the premise, showing stimulus figures playing on a playground and then going on to different school activities throughout the story (see Espy, 1997; Espy et al., 2005, for a more thorough description).

The Shape School has four experimental conditions, that are presented in a fixed order: (A) control; (B) inhibit; (C) switch; and (D) both.

Each test condition was preceded by a practical trial to ensure adequate rule knowledge and the children only proceed to the test if they named the stimuli correctly.

In the control condition (A), children are told that the names of the shape stimuli attending school are their colors and are asked to name the colors of 15 stimulus figures that are arranged in three lines of five across the page. This condition serves primarily as a baseline measure of processing speed. The subsequent conditions assess two different aspects of executive control.

In the inhibit condition (B), eight of the stimulus figures are shown with happy faces, whereas the remaining seven have a sad and/or frustrated expression. Children are told that in this classroom situation, the figures with happy faces have finished their work and are ready to go out for lunch, whereas those with unhappy faces are not. Correct responding in this condition requires a child to name the colors of the happy faced stimuli while suppressing those associated with the unhappy faced stimuli.

In the switch condition (C), some of the stimulus figures are wearing hats. The child is told that now in this classroom, the names of the figures wearing hats are their shape (square or circle) and that the names of the figures without hats remain their color. There are six figures wearing hats and nine without, in random order. Correct responding in this condition requires a child to be able to switch successfully between the two different responses (i.e., color vs. shape).

The both condition (D), the happy and sad faces are reintroduced for both hated and hatless figures, and the child received the instructing that only the happy figures are ready to participate in art class. The child has to concurrently suppress naming the sad figures (hated and hatless), name the shapes of the hated, happy-faced figures, and name the colors of the hatless, happy-faced figures. There are six hatted figures (three for each, happy and sad faces) and nine hatless figures, of these, are five happy and four sad-faced (Espy et al., 2006).

The response time and number of stimuli correctly identified (according to the pertinent rule) were recorded by the researcher, in each condition, from when the child began naming the first figure until finished naming the last figure in the array. Espy

(1997) proposed an efficiency score formula to be calculated for each condition [number of correct responses / total time].

Regarding the task demands, these are similar for conditions B and C, since both use identical verbal stimuli and naming responses. For both conditions, the first stimulus-response mapping (name color) provides proactive interference for the implementation of the second (B = suppress color name; C = name shape), in light of a relatively constant working-memory load of maintaining two rules in mind where overt cues signal the correct stimulus-response mapping. However, these conditions differ in relation to the type of inhibitory process demanded, with condition B requiring response suppression and condition C, the attention control (Espy and Bull, 2005).

Procedure

Following the authorization given by the original author (Espy, 1997) the test was translated into Portuguese. The procedure for translating the test instructions respected all contents and was performed by two professional translators with experience in this scientific field. A back-translation method was performed, resulting in two independent translations. After the discussion of these translations in a focus group, a final version of the Portuguese *The Shape School* was established (Appendix C).

Preschool children were administered *The Shape School* (*A Escola das Formas*, in Portuguese) in a single session by one trained researcher. Each session had an approximate time of 10 minutes and, generally, this occurred in the free time between teaching activities (not interfering in the time for meals and naps). Children were assessed individually in a quiet school room reserved for this purpose. Parents of all children tested provided informed written consent prior to their child's participation.

Results

This study deals with the preliminary adaptation of *The Shape School* and presents the performance of a sample of Portuguese children submitted to a translated and adapted version.

First, correlations among *The Shape School* condition -respective accuracies and latencies- were calculated. Table 1 shows the correlations within each condition. There was significance in the interrelations among the respective accuracies from all the conditions. Regarding to the latency, Condition A was not related to that of D, being this the only exception.

Then, Cronbach's alpha coefficients, computed with the responses to each of the stimuli within each condition, revealed adequate association in the conditions, A (α.81), B(α.67), C (α .62), and D (α .64).

Table 1. Correlations among *The Shape School* variables by condition.

Condition	A	B	C	D
	Stimuli correctly identified			
A#	-			
B#	**.43****	-		
C◊	**.48****	**.55****	-	
D◊	**.40****	**.57****	**.64****	-
	Completion time			
A#	-			
B#	**.43****	-		
C◊	**.26****	**.58****	-	
D◊	.15	**.34****	**.58****	-

Note: A= Control; B=Inhibit; C=Switch; D=Both; # *N*=137; ◊ *N*=125.

** $p < .01$.

Similarly to Espy (1997), a cross-sectional design was used to address whether *The Shape School* performance varies with age. The children were grouped by age and the means (and standard deviations) of each condition are presented in Table 2.

Note that children with 3 years-old typically underperform in the switch and both conditions (Espy, 1997). For this reason, only the children who completed these conditions are reported here.

There was a statistically significant difference between age groups on the efficiency, for all four conditions, as determined by one-way ANOVA (all *p*s <.01). In the control condition, efficiency varied significantly with age group ($F(2,134) = 18.79$, p =.000). A Tukey *post-hoc* test revealed that the 5-year-old children (0.87 ± 0.27) was statistically significantly more efficient compared to the 3-year-old (0.54 ± 0.20, *p*

=.000) and 4-year-old children (0.64 ± 0.25, p =.000). There were no statistically significant differences between the 3 and 4 years groups (p =.353).

A similar pattern of age-related performance was observed for the inhibit condition, with a significant overall age group effect ($F(2,134) = 20.52$, p =.000), and 5-year-old children significantly outperforming 3 and 4-year-old (ps =.000), with no significance between these last two (p =.669). Efficiency also varied significantly with age group in the switch and both condition ($F(2,122) = 22.54$, p =.000 ; $F(2,122) = 18.42$, p =.000, respectively), with greater efficiency observed in the older children compared with the youngest groups (ps =.000). Once more the significant related performance between 3 and 4-years-old groups was not observed (switch p =.276 ; both p =.200).

Table 2. *The Shape School* performance by age group.

Condition	Age 3		Age 4		Age 5	
	M	(SD)	M	(SD)	M	(SD)
*(A) Control**						
Number correct	14.60	(0.68)	14.83	(0.54)	14.92	(0.40)
Time (sec)	30.99	(17.00)	28.48	(17.51)	19.02	(6.72)
Efficiency score	0.54	(0.20)	0.64	(0.25)	0.87	(0.27)
*(B) Inhibit**						
Number correct	14.05	(1.19)	13.88	(2.66)	14.68	(1.04)
Time (sec)	29.28	(15.58)	26.44	(15.00)	16.84	(6.20)
Efficiency score	0.58	(0.27)	0.65	(0.32)	0.96	(0.31)
(C) Switch^{+}						
Number correct	12.22	(3.35)	13.15	(2.95)	14.36	(1.09)
Time (sec)	62.58	(24.26)	50.82	(19.46)	36.04	(10.29)
Efficiency score	0.21	(0.09)	0.29	(0.14)	0.42	(0.12)
(D) Both^{+}						
Number correct	12.78	(1.86)	12.85	(3.66)	14.04	(1.47)
Time (sec)	49.78	(13.93)	37.74	(17.87)	28.54	(10.51)
Efficiency score	0.27	(0.07)	0.37	(0.19)	0.54	(0.17)

Note: **n*=20 for age 3; *n*=42 for age 4; *n*=75 for age 5; $^{+}$*n*=9 for age 3; *n*=41 for age 4; *n*=75 for age 5. In switch and both conditions 11 children, under 48 months, were excluded because they didn't complete these tasks.

Discussion

The goal of this study was to translate, -performing the necessary adaptations-, and present preliminary data for the use of *The Shape School* test to Portuguese preschool-aged children.

Firstly, *The Shape School* items were associated adequately, demonstrated by acceptable Cronbach's alpha values for each condition and by consistent interrelations among condition accuracies and latencies. This corroborates the original test outcome.

Our results also confirm the findings of the American version, as the sensitivity of the measurement to age-related differences and the high numbers of stimuli named correctly, especially in the control and inhibit conditions.

This EF task performance differed among 3, 4, and 5 year-old children, with the older age groups outperforming the younger.

The efficiency score, taking into account both naming accuracy and speed, represents an effective measure of performance. Trough this index, our results revealed that the efficiency performance of the 5-years-old children stands out compared to the 3 and 4 years performance, with the latter two with closer score levels. This suggests that, although there is a visible improvement across age, it seems that the performance between 3 and 4 years is not as highlighted as with the oldest group.

Interestingly, the switch condition is the one with the lowest efficiency score and with the highest time to perform in all age groups, suggesting that the attention control under the ability to switch rapidly between different response sets is the more demanding EF component. Although this is more visible in Portuguese children, the most recent U.S. data also noted this trend (Espy, 2011).

Therefore, the adapted version seems suitable to obtain the discrimination among children of different preschool-ages. As in other studies (Espy, 1997; Pritchard and Woodward, 2011), our results also provide further evidence to support the utility of *The Shape School* as a measure of EF in typically developing samples.

The Portuguese test proved to be appropriate and useful for application in research and neuropsychological assessment settings. The existence of this version of the test will provide the access to the tool easily, encouraging other researchers and clinical technicians to use it. This is still an ongoing research and to perform validation of these preliminary results is expected to increase the sample. Studies oriented to the use of the test to assess special populations (e.g., learning disabilities) are also predicted.

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3.3 EXECUTIVE FUNCTIONS, FINGER COUNTING AND APPROXIMATE NUMBER SYSTEM (ANS) APTITUDE IN PORTUGUESE PRESCHOOLERS*

*The following research report has been submitted to publication as: Rato, J.R. and Castro-Caldas, A. (*submitted*). Executive functions, finger counting and Approximate Number System (ANS) aptitude in Portuguese preschoolers. *Mind, Brain, and Education.*

Abstract

A large body of research has already discussed the development of mathematical thinking. However, there are relatively few neuropsychological instruments to assess the early numeracy skills of young children. The present study aims to analyse whether the executive functions and finger counting can be components of the Approximate Number System (ANS) aptitude worthy of further investigation concerning early mathematical achievement. Participants were 30 typically developing children with 5 years-old (60-71 months; M=68, SD=2.78), attending a Portuguese private preschool. The Portuguese version of *The Shape School* (adapted by Rato and Castro-Caldas, 2012) was used to assess the executive functions (EF). The task *How many fingers?* was constructed to evaluate the finger counting. The ANS, i.e., the ability to instantly recognise how many are in a set without counting, was evaluated through the Panamath software (Halberda et al., 2008). Main findings reveal that children who have good performance at the inhibit condition (EF), also count more quickly the fingers and are faster to instantly recognize the quantity of dots (ANS). Our study supports the need for early assessment of these skills that seem to contribute to a better characterisation of emerging numeracy skills in preschoolers. Our discussion strengthens the effort for reforming mathematics education under the developing field of Educational Neuroscience.

Keywords: Executive functions; finger counting; approximate number system; preschool-aged children.

Introduction

Although, in recent years, there has been a growing interest in the numerical cognition, there are still many unanswered questions regarding the early mathematical skills of young children. One of these debating issues is related to the study of the neuropsychological components that would facilitate the math sense.

LeFevre et al. (2010) suggested that children's achievement in mathematics is predicted by a combination of number, spatial and language abilities. Supported by various fields of research, early spatial sense (with its main components, i.e., spatial visualization, insight into shapes and an understanding of space) was considered a key factor to the development of emerging number sense (Vans Nes and Lange, 2007). Butterworth (1999) goes further with a formalized model which considers the numerical representation built on three abilities; the ability to represent small numerosities (known as subitizing), the ability to mentally represent one's fingers (finger gnosis), and the ability to functionally use one's fingers (finger agility). Moreover, Butterworth asserts that each of these skills is the foundation for the normal development of number representations. According to Moeller et al. (2011) children with good finger-based numerical representations show better arithmetic skills and, in this sense, a training finger gnosis could actually enhance mathematical skills. Several research studies also linked the ability to focus, think, and to stop an impulse (executive function components) with achievement in maths (e.g., Bull et al., 2008; Clark et al., 2010) and science (Gropen, 2011).

Nowadays, the study of the Approximate Number System (ANS) is in the pipeline for many researchers. The ANS represents numerical information and is credited with the estimation of the magnitude of a group without relying on language or symbols, i.e., refers to a non-symbolic representation (Dehaene, 1997; Feigenson, Dehaene and Spelke, 2004; Gallistel and Gelman, 2000). Differences in ANS representations have been suggesting corresponding differences in mathematical ability (Libertus et al., 2011). Mazzocco et al. (2011) provided the first evidence for early ANS precision as a predictor of later mathematical abilities. This predictive relationship between early ANS acuity and later math ability has already been confirmed (Libertus, Feigenson and Halberda, 2013), highlighting the importance of early numerical estimation skills.

What is currently unclear is whether this range of neuropsychological functions, working in whole, it is really a facilitator of ANS acuity in preschool-aged children. In Portugal, there are few studies in this field, mainly due to the lack of measures to assess the number sense in preschoolers (Rato and Castro-Caldas, 2010). Therefore, the present study aims to analyse whether the executive functions and finger counting can be components related to the number sense (indexed by the ANS) worthy of further investigation concerning early mathematical achievement. Specific research questions included: Do executive functions and finger counting predict number sense (indexed by the ANS)? Does a more promptitude of fingers counting also means a good performance of number sense?

Method

Participants

Participants were 30 Portuguese children (20 boys and 10 girls) with 5 years-old (60-71 months; M=68, SD=2.78), attending a private preschool located in Lisbon. No child has a diagnosis, or is signalled, with developmental or learning disabilities. Socioeconomic status (as measured by parent levels) was fairly high, 67% of the participants' parents hold university degrees and 33% held post-graduate degrees (Master and Ph.D.).

Measures

Our neuropsychological assessment protocol is focused on three domains: (i) Executive Functions; (ii) Finger Counting; (iii) Approximate Number System. The arguments that served as a springboard to select these fields were: (i) The recent empirical evidence that highlighted the significant role that executive functions may have on emerging math skills (Espy et al., 2004; Mazzocco and Kover, 2007); (ii) The knowledge of the fingers and their use that seems to be associated with the mastery of calculus of children in the early years of schooling (Penner-Wilger et al., 2008); and (iii) Latest researches that have demonstrated a link between performance on approximate number system test and basic mathematical ability (Libertus et al., 2013).

(i) Executive Functions (EF):

For the evaluation of EF we used the Portuguese version of *The Shape School* test (adapted by Rato and Castro-Caldas, 2012; originally designed by Espy, 1997). This measure uses a colourful storybook and was designed to analyse the processes of inhibition and flexibility in preschoolers. The test is divided into four conditions, A, B, C and D. The condition A (baseline naming control) measures the speed of naming the colours correctly. In the condition B (inhibit/response suppression), it is possible to examine whether the child has the ability to inhibit a response. The condition C (switch / attentional control) allows recognizing whether the child has the ability to switch a response over another. Finally, regarding the condition D (both conditions - inhibition and switching) allows examining whether the child can inhibit a response and simultaneously perform the exchange of an automatic response by another conscious (Espy, 1997; Espy et al., 2006). The performance efficiency is calculated by the number of correct answers on the reaction time for each condition evaluated.

(ii) Finger Counting (FC):

The task *How many fingers?* was constructed to evaluate the FC, following the works of Andres et al. (2008), Noël (2005) and Penner-Wilger et al. (2007). Children viewed 10 pictures of two hands with 1 to 10 fingers raised (Portuguese canonical finger shapes). Children had to say the number of fingers raised out loud and at the same instant the experimenter typed in the child's response. To promote accuracy, the targets remained on the display until the child's response was entered by the experimenter. In this case, what is considered is the execution time of the task.

(iii) Approximate Number System (ANS):

To examine the ability to instantly recognize how many dots are in a set without counting, we developed the task *Where are more dots?* where children were instructed to tell in which group there was the highest number of dots (blue or yellow) presented on a screen during 1000 milliseconds. We use the Panamath software (Halberda et al., 2008) and we define two set of trials with different range of number of dots. There were 18 trials with the 1-15 range of dots and 18 trials with 5-21 dots. Totalling 32 test trials (preceded by two practice trials) that take approximately 2 minutes and 13 seconds to run. The Panamath method tracks two basic indices of the child performance: the accuracy at judging which colour had more dots and the reaction time.

Procedure

The research procedures described below were completed in accordance with approval from the school Board. Written consent was obtained from parents of all participants prior to testing. The testing sessions took place in child's school and all the children completed the measures in one twenty minute's session. All sessions were conducted in a classroom reserved for this purpose.

Our protocol is in computerized format and the tasks were presented to children through the game *Help Henry!* (in Portuguese, *Ajuda o Henrique!*) that we developed specifically for this study (Figure 1). The instructions are framed in the story, which refers to a boy, Henry, who entered in a maze and cannot get out without help. The child is encouraged to do various tasks in order to help Henry exit the maze. We used the SuperLab 4.0 and a 15.6-inch laptop screen, which was placed at a distance of 40 cm from the child.

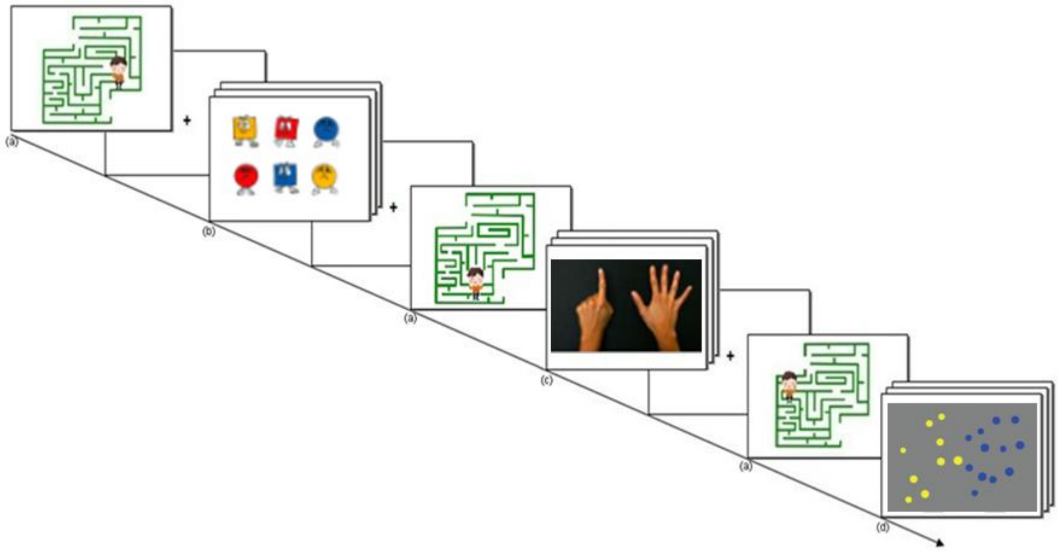

Figure 1: Schematic view of the three computerized tasks. (a) Game instructions *Help Henry!*, (b) Task *The Shape School*, (c) Task *How many fingers?* (d) Task *Where are more dots?*.

Results

The sample mean performance, i.e., accuracy and reaction time of the applied tasks, are shown in Table 1. Visual examination of the EF performance indicated that switch condition (C) has the lower efficiency score and the inhibit condition (B) has the highest score. The FC execution time ranged from 1967.9 to 5603.5 milliseconds, with no evidence of floor or ceiling effect. A paired-samples t-test was conducted to compare the averages between the two ANS trials. There were no statistically reliable differences in the mean of the correct percentage $t(29) = .96$, p=.344 or in the time to execute $t(29) = -.24$, p=809 of both trials (1 to 5 dots and 5 to 21 dots). These results suggest that the increased number of dots did not interfere in the mean performance of these trials.

Bivariate correlations between the EF efficiency scores, the execution time of the finger counting task and the scores of the two ANS trials are depicted in Table 2. Results reveal that the efficiency scores of the control, inhibit and inhibit/switch conditions was related to FC and ANS tasks.

Table 1. Descriptive information (*N*=30)

Measure	M	SD
EF A[1]	0.83	0.27
EF B[1]	0.90	0.29
EF C[1]	0.42	0.13
EF D[1]	0.52	0.17
FC RT[2]	3277.5	994.1
ANS 1_15[3]	83.13	13.35
ANS 1_15 RT[2]	1885.86	380.16
ANS 5_21[3]	81.04	12.00
ANS 5_21 RT[2]	1901.33	507.38

Note: EF-Executive Functions (A-D conditions); FC-Finger Counting; ANS-Approximate Number System.
[1]efficiency score; [2]milliseconds; [3]percentage correct.

Table 2. Intercorrelations among *The Shape School*, *How many fingers?* and *Where are more dots?* tasks (N=30)

	1.	2.	3.	4.	5.	6.	7.	8.	9.
1. EF A	-								
2. EF B	**.52****	-							
3. EF C	**.43***	.32	-						
4. EF D	**.38***	**.41***	.26	-					
5. FC RT	**-.38***	**-.42***	-.19	-.34	-				
6. ANS 1_15	.08	.11	.12	-.06	.16	-			
7. ANS 1_15 RT	-.34	**-.40***	-.22	**-.47****	**.48****	.15	-		
8. ANS 5_21	**.37***	**.39***	.15	.18	-.13	**.57****	-.07	-	
9. ANS 5_21 RT	.05	-.10	-.01	-.28	.31	**.39***	**.73****	.19	-

Note: ** *p*<.01; * *p*<.05.

EF-Executive Function	**FC-Finger Counting**	**ANS-Approximate Number System**
The Shape School	*How many fingers?*	*Where are more dots?*

The completion time of the FC and the percentage of correct answers of the ANS task (5-21 dots) were strongly correlated with the control and inhibit conditions; those children who have attentional control and stop the impulse, correctly indentified where are more dots in a set and took less time to identify the fingers quantity. The ability to inhibit further relates with the completion time to *where are more dots?* task, suggesting that the inhibition skill is adjacent to a rapid reaction time on instantly seeing where are more items (1-15 dots). This facility to immediately knowing how many items lie within the visual scene is also significantly correlated with the inhibit/switch condition and FC. Since the completion time of the ANS task (1-15 dots) is significantly correlated with two EF conditions (B -inhibit and D -inhibit/switch) and the FC completion time, multiple regression analysis by the stepwise model was performed (Table 3). The results showed the existence of two independent variables predictive of the ANS time performance, which explained, in total, about 34% of the variance of the model. The FC completion time and the EF efficiency score of both condition were the predictive variables found, which, each independently, explained 23% and 11% of variance, respectively.

Table 3. Regression coefficients and variance explained by ANS (1_15 RT)

Variable	R square	Beta	t value	p value
FC RT	.233	.483	2.918	.007
EF D	.341	-.350	-2.106	.045

Discussion

The predictors of mathematics have been broadly discussed, but, comparatively, few studies have examined which neuropsychological functions support the early numeracy abilities.

Our main results reveal that children who could inhibit a response more easily (crucial component of EF) may be in better position to form strong representations of number, since they also count more quickly the fingers and are faster to instantly recognize the quantity of dots (ANS), especially in trials with 1-15 dots. This finding adds to a growing body of evidence that stresses the importance of inhibitory related skills for achievement in math (Blair and Razza, 2007; Bull et al., 2008; Bull and Scerif, 2001; Espy et al., 2004). The same pattern occur with the control efficiency score, suggesting that children who have good naming processing speed also have sense of quantity, whether in the speed to count the fingers, either in the identification of the higher number of dots. The inhibit/switch skills also seem to be associated in the quicker category to the discrimination of quantities. Further, this component ability was found to be a predictor of ANS. This is consistent with the recent view that places the executive functioning as the key skill to provide a cognitive foundation for math learning (Kolkman et al., 2013). However, was also found that the finger counting has a greater predictive power for the ANS time performance. It is important to note that the significance between the reaction times of FC and ANS tasks, indicate that the child is so fast count fingers as it is to discriminate the quantity of dots, particularly in sets of 1-15 dots. In line with this finding, recent neurocognitive data indicated that finger gnosis is associated with children's numerical competencies, including computational skills (Noël, 2005; Penner-Wilger et al., 2007). This suggests a close link between finger counting and the representation of abstract number magnitude.

Though suggestive, the overall findings should be considered in the context of the sample characteristics, since it is a low-risk sample. Further studies that considered a wide range of status family level and learning disabilities will be needed.

In summary, our study stands up for the need for early assessment of these skills, since this seems to contribute to a better characterisation of emerging numeracy skills in preschoolers. These findings predominately support the emergent evidence that children's ability to control attention and action could be a strong predictor of academic performance, especially in maths domain (Blair et al., 2008). Further, this is in agreement that finger counting represents one of the basic number learning strategies (Sato et al., 2007), which mathematics education should promote rather than induce to abandon. Therefore, our discussion strengthens the effort for reforming mathematics education under the developing field of educational neuroscience.

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3.4 FROM EXECUTIVE FUNCTIONS TO NUMBER KNOWLEDGE: NEUROPSYCHOLOGICAL PERFORMANCE IN PRESCHOOLERS *

*The following paper has been submitted to publication as: Rato, J.R. and Castro-Caldas, A. (*submitted*). From executive functions to number knowledge: Neuropsychological performance in preschoolers. *Cognitive Neuropsychology.*

Abstract

Previous literature suggests that early number knowledge is under-assessed by neuropsychological tools, compared with other cognitive skills. In the present study we analysed the relation between component abilities (as the executive functions, visual-spatial working memory, subitizing and finger gnosis) and the early number knowledge, evaluating their predictive power. The sample comprised 35 typically developing children (19 boys and 16 girls) with 5 years-old (60-71 months; M=67.26, SD=5.43). Was used a neuropsychological assessment protocol developed for this purpose. Executive functions, subitizing and finger gnosis skills were found to be predictors of number knowledge. These components seem to contribute to performance on numerical tasks, and should be considered in mathematics education. Our findings support several views concerning the foundations of numeracy and have implications for the early identification of preschoolers' math skills.

Keywords: executive functions, visual-spatial working memory, subitizing, finger gnosis, number knowledge, preschoolers.

Introduction

Whether in education or in neuroscientific field, emerging number sense has been highlighted as a vital prerequisite to success in mathematics (Dehaene, 1997; National Council of Teachers of Mathematics, 2000). Previous literature reports suggest that a well-developed number sense allows children to understand number facts and algorithms more quickly and ultimately perform mathematical computations with great ease (Jordan et al., 2007). Given the importance of this construct, it seems obvious that number sense should be well-defined to be easily observed, assessed and explicitly taught through a developmentally systematic scope and sequence (Politylo et al., 2011). However, this is not the case, since number sense is a complex, intricate set of skills and finding one definition that gathers agreement between different authors and scientific fields is a hard assignment (Berch, 2005). There is a deep confusion in the basic terminology and this is typical when it comes to interdisciplinary studies. Therefore, and following previous studies (Östergren and Träff, 2013), the current study also avoids the term number sense and instead uses a broader term, "early number knowledge" (or "number knowledge").

According to some authors, the number knowledge can be divided into two classes of abilities (Geary, 1995; Jordan and Levine, 2009). First, two primary abilities (that develop informally and might not require deliberate practice) are the approximate number system (ANS), which is a system for number representation, and the subitizing (recently, also designated by object tracking system, OTS). The ANS represents non-symbolic numbers in an approximate way on a mental number line with no upper limit, whereas subitizing represents the small numbers (<5) estimation (Piazza, 2010). The secondary abilities already require deliberate practice to develop and are, for example, counting, symbolic numerical comparison, linear representation of symbolic numbers, and arithmetic operations. One of the cognitive number representation models that clarify and organize these classes of abilities is the von Aster and Shalev's (2007) hierarchical four-step model (Figure 1). In this model, an innate, core-system representation of cardinal magnitude and accompanying functions, such as subitizing and approximating (step 1) develops through the acquisition of number words (step 2) and Arabic numerals (step 3), which are then mapped onto the ANS, resulting in a symbolic mental number line (step 4), which in turn constitutes a precondition for developing more advanced mathematical abilities. A main assumption of this model is that the acquisition of the symbolic system (steps 2 and 3) and the establishment of the symbolic mental number line (step 4) are supported by domain-general cognitive abilities such as attention, executive functions, language, and working memory.

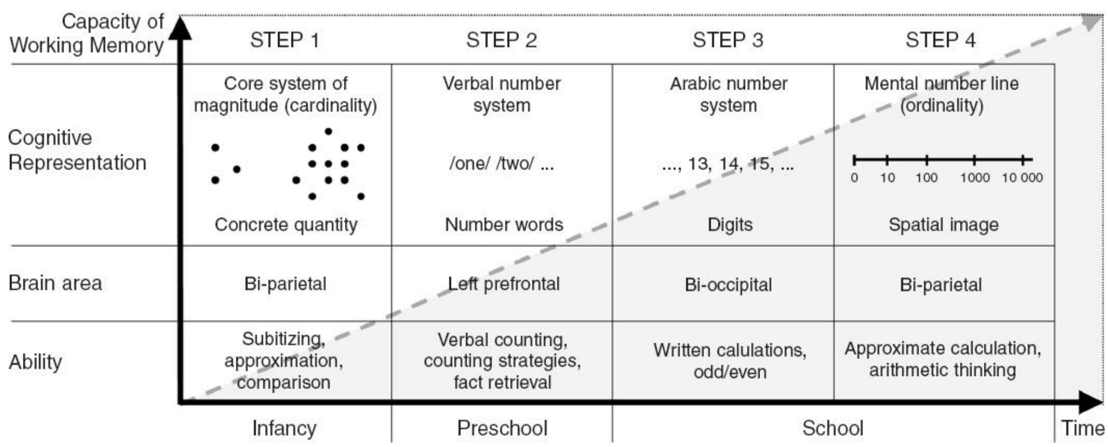

Figure 1. Scheme of the von Aster and Shalev's (2007) hierarchical four-step developmental model of numerical cognition.

The current study follows this view of the development of numerical cognition but it is focused only on steps 1 and 2 of the proposed model.

Research on the neuropsychological assessment of the early number knowledge of particularly preschool children (aged 5 years) is important because around that age children are building a more solid foundation for their math sense (Griffin, 2004), while, at the same time, they are expected to bridge their relatively intuitive and informal mathematical knowledge with the more complex mathematics of a formal school setting (Clements and Sarama, 2007).

Compared to literacy, considerably less is known about the precursors of numeracy. Recently, a growing body of research are using neuropsychological tools to investigate the precursor abilities that facilitate the numeracy development. The role that executive functions (Espy et al., 2004; Mazzocco and Kover, 2007), visual-spatial working memory (Reeve and Humberstone, 2011), and finger gnosia (Nöel, 2005; Penner-Wilger et al. 2007) may have on emergent math skills are some of the examples already studied, although analysed separately. However, evidence for this relationship on early number knowledge is still sparse. In Portugal this scenario gains a bigger dimension since there is a paucity of researches and adapted measures to assess these domains in preschoolers (Rato and Castro-Caldas, 2010). Therefore, this study proposes to address two research questions: 1) Are the component abilities (as the executive functions, visual-spatial working memory, subitizing and finger gnosis) related to number knowledge?; 2) Do these component abilities jointly and independently predict number knowledge?

Method

Participants

We collected data from 56 preschoolers. However, 21 children were not included in the final analysis due to failure to complete task (3), or equipment failure (18). Our final cohort for analysis was composed of 35 typically developing children (19 boys and 16 girls) with 5 years-old (60-71 months; M=67.26, SD=5.43). All of the children were Portuguese and Caucasian from a private preschool located on the outskirts of Lisbon (Portugal). According to teachers' reports, none of the children had any neurological or psychiatric diagnosis and all were right-handed. The education of the participants' parents was high; mostly of the parents hold university degrees (69%), 26% had masters or PhDs courses and 5% were postdocs.

Measures

A neuropsychological assessment protocol developed for this study was used with the following main domains of focus: i) executive functions; ii) visual-spatial working memory; iii) finger gnosis; iv) subitizing; v) number knowledge.

i) Executive Functions (EF):

The Shape School test was used to assess EF and the Portuguese version was adapted by Rato and Castro-Caldas (2012) from the original designed by Espy (1997). This measure uses a colourful storybook and was designed mainly to analyse the processes of inhibition and flexibility in preschoolers. The test is divided into four conditions, A, B, C and D. The condition A (baseline naming control) measures the speed of naming the colours correctly. In the condition B (inhibit/response suppression), it is possible to examine whether the child has the ability to inhibit a response. The condition C (switch / attentional control) allows recognizing whether the child has the ability to switch a response over another. Finally, regarding the condition D (both conditions - inhibition and switching) allows examining whether the child can inhibit a response and simultaneously perform the exchange of an automatic response by another conscious (Espy, 1997; Espy et al., 2006). The performance efficiency is calculated by the number of correct answers on the reaction time for each condition evaluated.

ii) Visual-spatial Working Memory (VWM):

To assess visual-spatial working memory, we developed a computer-task according to principles of the original Corsi Block Tapping (Corsi, 1972). This measure consists of nine blocks semi-randomly placed on a board and the subject has to repeat visuo-spatial sequences by tapping blocks in the correct order using memory. The Corsi Block tapping task was considered the most important nonverbal task in neuropsychological research (Berch, Krikorian and Huha, 1998).

Repeat Henry! (task linked with the game *Help Henry!* - for full description see the procedure section) is our variant of the Corsi blocks task, which uses a touch screen and asks children to reproduce a sequence of spatial locations in the same order in which they have been presented. Nine green buttons appear on the screen (nine circles with 3 cm diameter placed at the standard positions on a white background). The buttons will flash with the Henry's image after each other in a time of one per 1,000 msec, with an interstimulus interval (ISI) of 500 msec. Then the child has to follow Henry's sequence and touch on the buttons in the same order as Henry appeared in the screen. First, there are two practice trials. Then the testing trials start. The complete test condition consisted on three levels, each with five selected block sequences (with the sequence lengths between 1 to 3), which corresponds to a total of 15 sequences. We followed the block tapping sequences presented by Pagulayan et al. (2006). The children started by remembering sequences consisting of only one dot and then proceeded to successively higher levels until Level 3. The task ended after the child had incorrectly repeated two series with the same number of spots. No feedback was given to the child throughout this task. The efficiency score was calculated by using the sum of the correct number of taps achieved across the several trials and the completion time to execute them. The task was programmed in SuperLab 4.0 software, which recorded the child's responses in terms of reaction time and accuracy.

The *Repeat Henry!* task was initially piloted on an group of 12 children that were not considered for the final study. That preliminary testing allowed the identification of some weaknesses regarding the recording of the children's responses. One of the problems concerned the use of the touch screen, once the children's touches, were, sometimes, not strong enough. In this case, the accuracy and reaction time data could be compromised. Several modifications have been made, but still, it is possible that we haven't reached yet the final version of this task and new adjustments may be expected.

iii) Finger Gnosis (FG):

The FG measure is based on the tasks designed by Noël (2005) and Penner-Wilger et al. (2007). The *Which finger?* task was built especially for this study and pretends to analyse the ability to discriminate the fingers by the touch. Children were instructed to indicate as quickly and accurately as possible which finger was touched. Is required that they place their hands, palm down on a table with the fingers spread out, through the opening box so the experimenter could see them from the opposite side, but the children could not seem them. In each trial, the experimenter touches one or two of the child’s fingers and then removes the box and asks the child to point with the index finger of the other hand, to the finger(s) that have been touched. The sequence was randomly organised. The *Which finger?* task consisted in three forms of stimulation: isolated, successive and simultaneous. This task involved one practice and three test trials for each stimulation. All the trials were administered on each hand, beginning with the dominant hand. In each trial, the fingers were lightly touched below the first knuckle. First, isolated touches were performed. Then, successive touches of two fingers were administered and the correct response corresponds to the correct identification of the two fingers touched in the correct order. Finally, the simultaneous touches was conducted, also with two fingers and with the same score rule. All correct responses were scored as 1, giving a maximum of 30.

iv) Subitizing (Sb):

We developed the task *Where are more dots?* to examine the ability to instantly seeing how many dots are in a set without counting. In this non-symbolic numerical comparison task the children were instructed to tell in which group was the highest number of dots (blue or yellow) presented. We used the Panamath software (Halberda et al., 2008) and defined two sets of trials with 1-3 range of dots and 4-6 dots, totalling 16 test trials (preceded by two practice trials) that take approximately 2 minutes and 43 seconds to run. The numerosity ratio between the two sets varied randomly among 1.41 and 1.63. The colour of the sets also varied randomly, and half of the trials were area-controlled to ensure that responses were on the basis of the number of dots and not on the total dot area (size control 0.0 and -1.0). The children sat at a computer as a series of slides with varying numbers of yellow and blue dots flashed on a screen for 1000 milliseconds.

Response times were measured from the point at which the stimuli appeared until the experimenter pressed the key (to the correct or incorrect answer) when the child spoke their response. The accuracy and reaction time was registered by the Panamath software.

v) Number Knowledge (NK):

The *Number Knowledge Test* was designed by Okamoto and Case (1996) with the goal of assess children's understandings of the system of whole numbers from 4 to

10 years old. The NK test contains four levels and students are required to obtain a minimum number of correct responses at one level to move to the next level. On Level 1, counting chips and geometric shapes are some of the examples of the requested tasks. Level 2 requires students to do tasks such as identifying bigger or smaller numbers from a pair, naming numbers, and solving simple addition and subtraction problems. Level 3 requires students to solve problems similar to those of Level 2, but with larger numbers. Level 3 also requires students to complete new items such as stating how many numbers are between a pair of numbers. Level 4 is a more difficult version of Level 3 and also adds new tasks such as telling which difference between two pairs of numbers is bigger or smaller.

In this study, the test was only applied until Level 3, and only few children reached to that level. According to the authors, at Level 1, children are expected to count by rote and to quantify globally but not to connect number and quantity (4 years-old), and, at Level 2, children are expected to have constructed a mental counting line that integrates their understanding of numbers and quantities (6 years-old). The NK test is an oral test and requires oral responses from each child. For this study we used the Portuguese translated version (Rato and Castro Caldas, 2012; see Appendix D).

Procedure

The same test order was used for all children, and all testing was performed in a quiet room at the child’s school. All tasks were administered individually and most of the instructions were presented through the game *Help Henry!* (in Portuguese, *Ajuda o Henrique!*), which was developed specifically for this study. This game tells about a boy, Henry, who entered in a maze and cannot come out if not helped. The children are encouraged to do the several tasks in order to help Henry getting out of the maze. We used SuperLab 4.0 for this computerized tasks and it were presented trough a 15.6-inch Acer Aspire touch-screen that was placed at a distance of approximately 50 cm from the child at an appropriate angle. The instructions of the tasks not computerized (*Which finger?* and NK test) were presented orally by the researcher, but these tasks were also linked to the game.

For each child, there was a written consent form completed by one of the parents. The children were free to participate in the study and could leave the testing whenever they wanted, but no one did. All children completed the tasks in a single session of approximately an hour. The study was conducted in accordance with the Human Ethics Committee requirements.

Results

Descriptive analyses were conducted with SPSS (Statistical Package for the Social Sciences - version 16.0 for Windows). Means and standard deviations for all measures are reported in Table 1.

Table 1. Descriptive information for measures (*N*=35)

Measure	Max. Score	M	SD
	Executive Functions		
Control[1]		0.83	0.25
Inhibit [1]		0.89	0.27
Switch [1]		0.42	0.12
Both [1]		0.52	0.18
	Visuo-spatial Working Memory		
Memory span[1]		0.38	0.18
	Finger Gnosis		
Isolated[2]	10	8.83	1.27
Successive[2]	10	5.71	2.08
Simultaneous[2]	10	5.23	2.17
	Subitizing		
Subitizing[4]		90.00	10.08
Subitizing RT[3]		2176.32	683.40
	Number Knowledge		
Level 1[2]	5	4.83	0.38
Level 2[2]	10	4.34	1.63

Note: [1]efficiency score; [2]number correct; [3]milliseconds; [4]percentage correct.

The index of the number knowledge levels (i.e., counting - Level 1, or the identification of bigger or smaller numbers - Level 2) were entered separate on the analysis performed. Note that the scores on the isolated touching (finger gnosis), subitizing and the Level 1 of number knowledge test were nearly at ceiling effect. In the finger gnosis case, Nöel (2005) also verified this result; as to subitizing, Gelman and Tucker (1975) also reported 90% of accurate responses in 5-year-old children for a set of three items; and concerning the number knowledge test, this performance is within the standard since it is expected that the 4 year-old-children reach this level.

To determine whether the neuropsychological component abilities reflect separate abilities and whether these component abilities are related to numeracy skills, correlational analyses were performed. Intercorrelations among the measures are shown in Table 2.

Table 2. Intercorrelations among measures (*N*=35).

		1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.
EF	1. Control	-											
	2. Inhibit	**.51****	-										
	3. Switch	**.42***	.32	-									
	4. Both	**.40***	.32	.25	-								
VWM	5. Memory span	-.09	-.13	.07	-.12	-							
FG	6. Isolated	.24	.16	.11	.01	-.11	-						
	7. Successive	.17	.15	.28	.11	.19	**.42***	-					
	8. Simultaneous	-.04	.07	.12	-.10	.13	.31	**.49****	-				
Sb	9. Subit. PC	.28	.30	.27	.31	.03	**.41***	.16	.07	-			
	10. Subit. RT	-.14	-.25	-.10	-.11	-.02	-.11	-.19	-.02	**-.49****	-		
NK	11. Level 1	.13	**.38***	.17	.08	.11	.18	.31	.01	**.35***	**-.46****	-	
	12. Level 2	**.34***	.12	**.34***	**.38***	.10	.10	**.36***	.15	.01	-.13	.10	.05

Note: $^{**}p<.01$; $^{*}p<.05$.

EF- Executive Function
VWM- Visual-spatial Working Memory
FG- Finger Gnosis
Sb- Subitizing
NK- Number Knowledge

Notably, there were no significant correlations among the three component abilities - executive functions, visual-spatial working memory and finger gnosis -, supporting the view that they represent separate abilities. As predicted, executive functions, subitizing and finger gnosis skills were significantly correlated with number knowledge. Note that inhibition is related with number knowledge -Level 1 and the other three EF components are related with number knowledge -Level 2. Subitizing also appears related with number knowledge -Level 1, but finger gnosis (by the successive stimulation) is related with number knowledge -Level 2. In contrast to expectations, no interaction reached significance between visual-spatial working memory and number knowledge.

To determine whether the component abilities predict numeracy knowledge, both jointly and independently, regressions were performed.

Multiple regression analyses revealed that subitizing, inhibition/switching efficiency and finger gnosis have predictive value to number knowledge (considering each level separately). The significant paths are represented in Figure 2. First, the results of this analysis indicate that completion time to execute subitizing tasks (β = -.46, $p<.01$) accounted for a significant proportion of variance in the number knowledge (Level 1), $R^2 = .22$, $F(1, 33) = 9.07$, $p <.001$, indicating that children who had more promptitude to instantly seeing how many items tended to have higher scores on the beginner level of number knowledge. Second, number knowledge (Level 2) was predicted from the component abilities: executive functions (by the both condition) and finger gnosis (by the successive touch), $R^2 = .25$, $F(2, 32) = 5.25$, $p <.01$. As shown in Figure 2, the executive functions (β = .35, $p<.05$) and finger gnosis (β = .32, $p<.05$) accounted uniquely 12% and 8%, respectively, of the 20% of variance accounted for by the entire model.

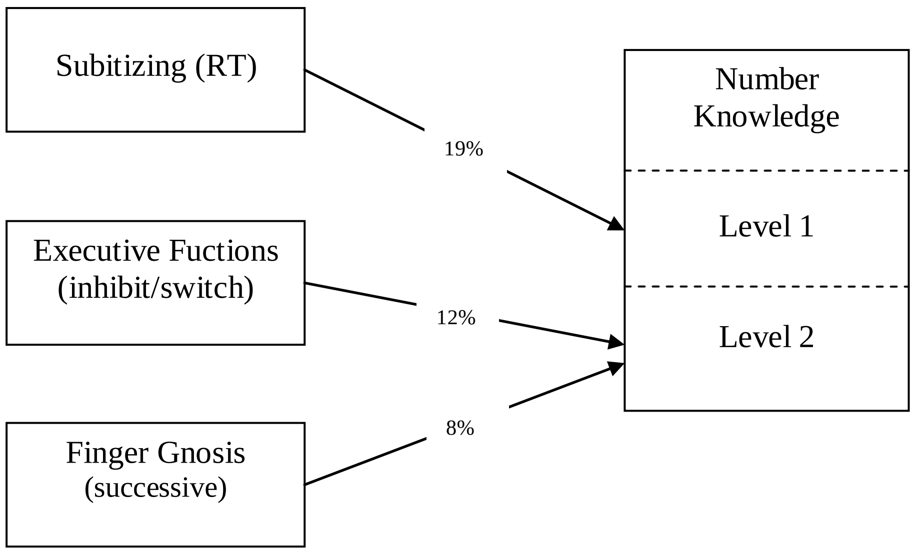

Figure 2. Regression models with the variance accounted from the significant components considering each level of number knowledge separately.

Discussion

In the current study we investigated whether executive functions, visual-spatial working memory, finger gnosis and subitizing are related to preschooler's numeracy knowledge. In a series of correlations and regressions we found that preschoolers with strong executive functions, subitizing and finger gnosis had better early number knowledge.

More specifically, the executive functions components seem to contribute differently to performance on numerical tasks, since control, switch and both conditions was significantly related with Level 2 of number knowledge and the inhibit condition was associated to a beginning level of number outcome (Level 1). Thus, the inhibition skill and basic number knowledge could be closer to an automated process. The results also showed that both condition, i.e., shifting and inhibition considered together, might be a more important predictor of numerical skills than taken separately. This might suggest that these abilities jointly represent a cognitive flexibility that work as a conductor of numeracy knowledge. Our findings directed us to agree with Anderson and Reidy (2012), who defend that the benefits and opportunities for executive function assessment and its intervention in the preschool period has to be more considered by educational and health technicians.

Furthermore, the significant negative correlation between subitizing reaction time and number knowledge (Level 1) indicates that a higher performance on counting (since it is the main skill assessed in this level) was associated with a lower time to execute subitizing task. Therefore, this could indicate that greater interference was due to a higher sense of quantity. The predictive value confirms this possibility and, thus, children who show quickness in the enumeration of small sets of items are better in the counting process. These findings provide further support that subitizing skill may be foundational for mathematics development in early childhood. In this line, it may be useful to consider subitizing as a screening tool that could provide a rough estimate of children’s mathematical abilities, an idea that has been suggested by other authors (Desoete et al., 2009; Yun et al., 2011). Another interesting result is the subitizing skills linked to finger gnosis, even when both are closer to the ceiling effect. Indeed, the correlational analysis did reveal that greater performances in enumerating small sets of items without counting are related with good representations of the fingers, especially when it comes to the isolated touch stimuli. There are recent studies that relate finger counting to the Approximate Number System, i.e., estimation of sets greater than four items (Rato and Castro-Caldas, 2013), but this relation between subitizing and finger gnosis skill appears to be the first evidence reported and triggers for more research in this field.

Regression analyses results also revealed that there are unique contributions from finger gnosis in predicting number knowledge. The successive stimulation of two fingers further than seem to be the most distinctive in the assessment of this domain (since the performance on the isolated touching was nearly at ceiling) is also the best predictor regarding the ability to recognize numerosity. This evidence supports a role for fingers in math development and is consistent with previous studies (Fayol, Barrouille and Marinthe, 1998; Noël, 2005; Penner-Wilger et al., 2007), in which the finger gnosis performances predicted children’s math performance both concurrently and longitudinally. Thus, children able to use their fingers as representational tools had better numeracy skills.

The no significant correlation between the visual-spatial working memory and number knowledge (or even the subitizing) is intriguing. One possible explanation for why this sort of memory did not predict with numeracy outcomes is that there may be different developmental paths to numeracy or different combinations of skills that produce a favourable outcome. This possibility would not be consistent with others views (e.g., Geary, 1994), given the necessary roles for visuo-spatial memory in the developmental of numeracy. So, the previous limitations found in our measurement of this domain, could still be an issue, since the fragility on the procedure to collect children responses may have affected the results. Future studies should ensure that this task is more reliable.

Nevertheless, our main findings support several views (e.g., Espy et al., 2004; Butterworth, 2004) concerning the foundations of numeracy and highlight the need for the early screening of preschoolers' math skills.

Taken all together, it appears that this study contributes to further understand the role of these components abilities in the performance on numerical tasks. We think that studies like this is imperative considering national context and should have implications in mathematics education. A successful interdisciplinary interaction between cognitive neuroscience and education, since early years, seems a crucial way to overcome the bad raking position on math achievements.

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4 CONCLUSIONS AND OUTLOOK

The main aim of this research work is to gain a more in-depth understanding of how the educational neuroscience field could underpin educational subjects. Thus, the current thesis is organized around two main approaches, in which were studied two different populations.

Concerning the main findings of the first approach, the studies 1 and 2 provided evidence of the teachers' interest and acknowledge of the potential of neuroscientific information in education. Notwithstanding, in the study 2 was found out a gap between the teachers' interest and their proficiency in the interpretation of scientific information, since the majority showed difficulty in distinguishing myths from facts. This confirms that the attention on these matters is growing in Portugal, but still far from the international discussions in this field. This is an on-going debate with many barriers to overcome and much clarification work to achieve. One of the most important things to work with teachers is the demonstration of the real benefit that education could receive from neuroscientific research. The current studies suggested that it is important to support a translational process to provide opportunities for teachers and neuroscientists to collaborate and, thus, stop the spreading of neuromyths in the educational community. The educational and neuroscientific community should understand that the value of this cooperation is invaluable. It is essential to realize that neuroscience is to education what, for example, biology is to medicine. Biochemistry is not enough to cure a patient, but it is impossible to perform a reliable work against the laws of biology. The same happens with the study on learning process without an educational neuroscience view. Modern societies increasingly demand education based on scientific evidence. In this line, further work should arise towards the application of what is known about human neurocognition to the classroom practice.

Regarding the neuropsychological assessment, i.e., the second approach discussed here, the study 3 that focused on adapting *The Shape School* test demonstrated that the Portuguese version seems suitable to obtain the discrimination among children of different preschool-ages and brings an added value to clinicians, since it proved to be appropriate and useful for application both in research or neuropsychological assessment settings. This reinforces the view that the executive functioning should continue to be a focus on early neuropsychological assessment, since it could be the conductor of the brain's orchestra and provide a cognitive foundation for learning. The studies 4 and 5 also support the need for early assessment of the component abilities analysed, which seem to contribute to a better characterisation of emerging math skills in preschoolers. The main findings reveal that the children with strong executive functions, subitizing and finger gnosis had better early number knowledge. Further, was found the predictive relation between some component abilities and early math skills. In the case of study 4, the executive functions and finger counting was the precursors' abilities that seems facilitate the ANS aptitudes. On study 5, the executive functions, finger gnosis and subitizing, each independently, predict the number knowledge. In both studies the inhibit/switch condition appears highlighted and is the executive functions component with more predictive power. In sum, the several studies conducted provide a novel and clear evidence that neuropsychological assessment is crucial to better understand the underpinnings of early number knowledge. Knowing, for example, whether and how executive functions and number knowledge are related has theoretical and practical implications. These implications include, but are not limited to, the development of a testable model of emergent mathematical ability and disability, and the provision of information relevant to math instruction and intervention for both typically-developing children and children at risk of math difficulties.

However, and as with any research study, the conclusions drawn must be viewed within the context of the study limitations. Foremost of the limitations is external validity. The samples for the studies 4 and 5 were relativity small and highly specific in terms of geographic location and socioeconomic status, not allowing the generalization of the results. One of the major difficulties was collecting authorizations from children parents, since that 212 informed consent requests remained unanswered. Nevertheless, to determine whether the measures hold promise for a more general population, further research is needed. Regarding the measures developed, in particular, the *Repeat Henry!* task, several failures were detected, mainly the way to record properly the children' responses. Since the results using this tool did not correspond to expectations, this technical fragility was probably the reason that affected them.

With this work it is expected to have contributed to highlight the need of scientific validity for reforming mathematics education, mainly under the developing field of educational neuroscience. Teachers have a wide range of instructional strategies at their disposal. Depending on the subject and on the level at which it is being studied, teachers must decide what material to present, and when and how to present it. The several findings achieved with the current research work make believe that educational neuroscience could help teachers in this work (preceded by a neuropsychological assessment) and this should be developed in a context of interdisciplinarity.

Taken together, this thesis discloses an important debate between neurocognitive and mathematics education research concerning the benefits of the strategies embodied in the educational neuroscience field for numerical skill enhancement or improvement. Fortunately, the number of research projects at the intersection of neuroscience and education is now emerging and there is a new generation of forthcoming researchers who do not belong to either one of these fields but identify themselves as belonging to the interdisciplinary research area of educational neuroscience. This opens new avenues for broadening methodological repertoire and for deepening the understanding of learning and instruction.

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Appendix A

APPENDIX: Questionnaire Neuroscience and Education
[This is an excerpt from a longer questionnaire, translated from Portuguese]
Rato, Abreu, & Castro-Caldas (2010). ICS, Universidade Católica Portuguesa.

Dear Teacher,
We ask for your cooperation by answering the questionnaire below.
Your answers are intended solely for research purposes. Please respond to all items, otherwise your answers will be discarded.

Age: Male □ Female □ Educational stage tought:
Area of expertise: Number of years of experience as a teacher:

1. Please indicate how much importance you attribute to the understanding of brain functions on the:

	Not important	**Very important**	**Don't know**
1. Design of educational programmes			
2. Application of teaching strategies			
3. Early screening for learning problems			
4. Decisions about curriculum content			
5. Support children with cognitive SEN			
6. Support children with physical/sensory SEN			
7. Support children with emotional SEN			
8. Role of nutrition in educational performance			

2. According to your opinion indicate if you **Agree**, **Disagree**, or, **are not familiar with (Don't know)** the following propositions.

To achieve a successful relationship between neuroscience and education what is necessary?

Propositions	**Agree**	**Disagree**	**Don't know**
1. Further training for teachers.			
2. Neuropsychologists as mediators to link the brain science to education.			
3. Research schools (more studies that interrelate a neuroscientific perspective with a school setting).			
4. Neuroscientific answers to all questions concerning education.			
5. The creation of a new transdisciplinary science.			
6. Shared vocabulary between neuroscientists and educators.			
7. Debunking brain myths.			
8. Collaboration between schools and universities.			
9. Two-way dialogue amongst educators and neuroscientists.			
10. Spread of programs such as Brain Gym.			
11. Clarification of ethical issues in brain research.			
12. Shared databases on learning and development.			
13. Conferences involving neuroscientists and teachers.			

Appendix B

APPENDIX: Questions from the Neuroscience and Education Questionnaire Instrument used in the study.
[This is an excerpt from a longer questionnaire, translated from Portuguese]

1. Please indicate some ideas or concepts that you have heard of, in which the brain is linked to education.

2. Which of the following sources have provided you with information concerning the brain's role in education?
   (a) Television □
   (b) In-service training □
   (c) Internet □
   (d) Conferences □
   (e) Scientific journals □
   (f) Books □
   (g) Others □ ____________________

3. Does your institution use brain-based techniques? Yes □ No □ Don't know □
   If so, which techniques you use?

4. Regarding the classification: **Myth**, **Fact**, or, **'I don't know'**, please choose which seems appropriate for each assertion.

In educational practice we have to consider that:	**Myth**	**Fact**	**I don't know**
1. The left and right brain work independently.			
2. Neuroplasticity allows the brain to organize itself according to the information it receives.			
3. We only use 10% of the brain.			
4. There are separate types of intelligence (e.g., interpersonal, logical; with different IQs).			
5. Drinking extra water (even when one is no longer thirsty) is vital for brain function.			
6. Learning styles should be based on multi-sensory pedagogies (VAK model).			
7. Learning two or more languages develops brain function.			
8. Students should be given vitamin supplements or other medications to learn better.			

Thank you for your participation.

Appendix C

The Shape School ©
A Escola das Formas

Tradução e adaptação para o Português Europeu:
Joana Rato & Alexandre Castro-Caldas (2011). Instituto de Ciências da Saúde, Universidade Católica Portuguesa.

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A Escola das Formas

MANUAL DE INSTRUÇÕES

Nota prévia:

Primeiro pedir à criança que nomeie as cores (vermelho, azul e amarelo) e as formas (quadrado e círculo).

Durante o teste aceita-se que a criança diga cubo para quadrado e bola para círculo.

Aceita-se também encarnado para vermelho.

Ao longo do teste pode repetir-se a instrução apenas nas tarefas de treino.

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A Escola das Formas

Instrução:

Esta é a Escola das Formas.

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A Escola das Formas

Vermelho – Amarelo - Azul

Instrução:

Existem duas turmas na Escola das Formas.

O Professor Círculo tem uma turma com três crianças.

Os nomes das crianças são as suas cores.

Diz-me qual é o nome das crianças da turma do Professor Círculo.

Qual é o nome deste (apontar para o vermelho)?

E deste (apontar para o amarelo)?

E deste (apontar para o azul)?

Nota: Se a criança errar deve-se confrontá-la com a cor "original". Se mesmo assim continuar a errar, volta-se ao início (nomeação das cores).

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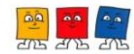
A Escola das Formas



Amarelo – Azul - Vermelho

Instrução:

A Professora Quadrado também tem uma turma com três crianças.

Diz-me qual é o nome das crianças da turma da Professora Quadrado.

Quem é este (apontar para o amarelo)?

E este (apontar para o azul)?

E este (apontar para vermelho)?

Nota: Se a criança errar deve-se confrontá-la com a cor "original". Se mesmo assim continuar a errar, volta-se ao início (nomeação das cores).

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Instrução:

Todas as crianças das duas turmas estão em fila para ir brincar para o recreio.

Diz-me o nome das crianças que vão sair para brincar, o mais rápido que conseguires, sem te enganares nenhuma vez.

Começas aqui e dizes o nome das crianças, uma de cada vez, por esta ordem (apontar com o dedo), sem saltar nenhuma.

Estás pronto? Podes começar.

Nota: Começar a cronometrar o tempo. Na folha de registo, assinalar as respostas pela ordem que foram ditas pela criança. Se a criança apontar com o dedo enquanto diz o nome das crianças deve-se fazer o registo nas observações.

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Vermelho - Amarelo

Instrução:

Agora está na hora do almoço, mas nem todas as crianças podem ir almoçar.

Só as crianças que têm caras contentes, como estas (apontar), é que estão prontas para ir almoçar.

Diz-me o nome das crianças que estão prontas para almoçar.

Quem tem uma cara contente?

Nota: Se a criança errar, deve-se apontar para o amarelo e depois para o vermelho e dizer: A criança amarela e a criança vermelha têm caras contentes.

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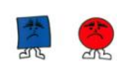

Não dizer o nome

Instrução:

Estas crianças não estão prontas para ir almoçar.

Elas têm caras tristes.

Quando jogarmos o próximo jogo, não podes dizer o nome das crianças que têm cara triste.

Então, se visses a criança azul na fila, ias dizer-me o nome dela?

Não, ela está triste e tu não podes dizer o nome das crianças com caras tristes.

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Amarelo – Vermelho – Azul

Instrução:

Agora, estão aqui algumas crianças para tu praticares. Diz-me o nome das crianças com a cara contente.

As crianças que estão com cara triste não estão prontas para ir almoçar, então não podes dizer o nome delas.

Percebeste? Vamos praticar.

Nota: Se a criança errar, pede-se para repetir.

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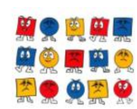
A Escola das Formas



Instrução:

Muito bem! Agora todas as crianças de todas as turmas estão aqui.

Quero que me digas o nome das crianças com caras contentes o mais rápido que conseguires, sem nenhum erro. Começas aqui (apontar) e dizes o nome de cada criança, uma de cada vez, sem saltar nenhuma.

Lembra-te, diz-me o nome das crianças com cara contente e não me digas o nome das crianças com cara triste.

Percebeste? Prepara-te. Podes começar.

Nota: Começar a cronometrar o tempo. Na folha de registo, assinalar as respostas pela ordem que foram ditas pela criança. Anotar o tempo total.

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A Escola das Formas

Amarelo – Vermelho – Quadrado – Azul – Círculo - Vermelho

Instrução:

Todas as crianças acabaram de almoçar. Agora é a hora da história.

A turma da Professora Chapéu também vai ler histórias. As crianças da turma da Professora Chapéu estão a usar chapéus. Elas têm o nome das suas formas.

Todas as crianças estão em fila para ir à hora da história. Vais-me dizer o nome das crianças que estão a ir para a hora da história.

Lembra-te, o nome das crianças sem chapéu é a sua cor e o nome das crianças com chapéu é a sua forma.

Percebeste? Vamos praticar.

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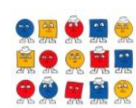
A Escola das Formas



Instrução:

Muito bem! Agora é a hora da história. As crianças de todas as turmas estão em fila. Vais-me dizer o nome das crianças que estão a ir para a hora da história o mais rápido que conseguires sem dares nenhum erro.

Começas aqui (apontar) e dizes o nome de cada criança, uma de cada vez, sem saltar nenhuma.

Percebeste? Prepara-te. Podes começar.

Nota: Começar a cronometrar o tempo. Na folha de registo, assinalar as respostas pela ordem que foram ditas pela criança. Anotar o tempo total.

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A Escola das Formas

Vermelho – Quadrado - Amarelo

Instrução:

Quando as crianças acabam a história podem ir à hora das artes. Mas nem todas as crianças acabaram a história.

As crianças que não acabaram a história têm cara triste. Elas não estão prontas para a aula das artes, por isso não me digas o nome delas.

As crianças com cara contente acabaram a história. Elas estão prontas para a aula das artes, portanto diz-me o nome delas. Lembra-te, que a cor é o nome das crianças sem chapéu e a forma é o nome das crianças com chapéu.

Percebeste? Vamos praticar dizendo o nome das crianças que estão prontas para a aula das artes.

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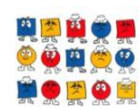
A Escola das Formas



Instrução:

Muito bem! Agora é a hora das artes. Todas as crianças estão em fila. Vais-me dizer o nome das crianças que estão prontas para ir para a hora das artes o mais rápido que conseguires sem dares nenhum erro. Começas aqui (apontar) e dizes o nome de cada criança, uma de cada vez, sem saltar nenhuma.

Lembra-te, diz o nome das crianças com cara contente e não digas o nome das crianças com cara triste. A cor é o nome das crianças sem chapéu e a forma é o nome das crianças com chapéu.

Percebeste? Prepara-te. Podes começar.

Nota: Começar a cronometrar o tempo. Na folha de registo, assinalar as respostas pela ordem que foram ditas pela criança. Anotar o tempo total.

The Shape School© - A Escola das Formas

Folha de respostas

Nome: ____
Data de Nascimento: ____/____/_____ Idade: _______
Data : ____/____/____Examinador: __________________

Condição A – Base de nomeação de controlo

amarelo	**vermelho**	**azul**	**amarelo**	**azul**	**Tempo:**	________ **segundos**
azul	**amarelo**	**vermelho**	**azul**	**vermelho**	**#C Corretas:**	______________
amarelo	**vermelho**	**azul**	**amarelo**	**vermelho**	**#C Erradas:**	______________
					Eficiência:	______________

Condição B – Inibição de resposta

vermelho	**INIBIÇÃO**	**amarelo**	**vermelho**	**INIBIÇÃO**	**Tempo:**	________ **segundos**
azul	**amarelo**	**INIBIÇÃO**	**azul**	**INIBIÇÃO**	**#I Corretas:**	______________
INIBIÇÃO	**INIBIÇÃO**	**azul**	**INIBIÇÃO**	**vermelho**	**#C Corretas:**	______________
					#I Erradas:	______________
					#C Erradas:	______________
			#T Corretas:	___________	**Eficiência:**	______________

Condição C – Troca de resposta

azul	**amarelo**	**CÍRCULO**	**azul**	**CÍRCULO**	**Tempo:**	________ **segundos**
QUADRADO	**vermelho**	**amarelo**	**QUADRADO**	**azul**	**#F Corretas:**	______________
vermelho	**CÍRCULO**	**vermelho**	**QUADRADO**	**amarelo**	**#C Corretas:**	______________
					#F Erradas:	______________
					#C Erradas:	______________
			#T Corretas:	___________	**Eficiência:**	______________

Condição D – Ambas as situações

azul	**INIBIÇÃO**	**QUADRADO**	**INIBIÇÃO**	**INIBIÇÃO**	**Tempo:**	________ **segundos**
amarelo	**CÍRCULO**	**azul**	**INIBIÇÃO**	**azul**	**#I Corretas:**	______________
INIBIÇÃO	**INIBIÇÃO**	**INIBIÇÃO**	**vermelho**	**QUADRADO**	**#F Corretas:**	______________
					#C Corretas:	______________
					#I Erradas:	______________
					#F Erradas:	______________
					#C Erradas:	______________
			#T Corretas:	___________	**Eficiência:**	______________

Observações:____
____
____

#I: Número de Inibições
#C: Número de Cores
#F: Número de Formas
#T: Total de respostas
Eficiência: (corretos /tempo)

Appendix D

TESTE DE CONHECIMENTO NUMÉRICO

(The Number Knowledge Test -NKT; Okamoto & Case, 1996)

Nível Preliminar

Sabes contar? Conta até onde souberes. Podes começar. R:___

Nível 1 (*Passagem para o nível seguinte se tiver 3 ou mais correctos*)

1. "**Eu vou te mostrar algumas fichas**. [Mostrar uma variedade de fichas misturadas sendo 3 vermelhas e 4 azuis]. **Conta as fichas azuis, e diz-me quantas são**." | 4

2. "**Aqui temos alguns círculos e triângulos**. [Mostrar uma variedade misturada de 7 círculos e 8 triângulos]. **Conta somente os triângulos, e diz-me quantos são**". | 8

3. "**Eu vou te dar 1 rebuçado e depois vou te dar mais 2** [Realize a ação]. **Quantos rebuçados tens ao todo?**" | 3

4. "**Eu vou te dar duas pilhas de fichas**. [Mostre um empilhado com 5 fichas vermelhas e um empilhado com 2 fichas azuis]. **Qual é a pilha que tem mais?**" | v

5. "**Preferias ter 5 rebuçados ou 2 rebuçados? Por quê?**" R:____ | 5

Nível 2 (*Passagem para o nível seguinte se tiver 5 ou mais correctos*)

1. "**Se tivesses 4 chocolates e se alguém te desse mais 3, com quantos chocolates tu ficarias no total**?" | 7

2a. "**Que número vem logo depois do 7?**". | 8
2b. "**Que número vem 2 números depois do 7?**" | 10

3a. "**Qual é o maior, 5 ou 4?**". | 5
3b. "**Qual é o maior, 7 ou 9?**" | 9
3c. "**Qual é o menor, 8 ou 6?**" | 6
3d. "**Qual é o menor, 5 ou 7?**" | 5

4a. [Apresentar o triângulo matriz contendo os números 5, 6, 2.] "**Qual é o número mais próximo do 5?** [Apontar para o 5] **É o 6 ou o 2?**". [Apontar cada número na sua vez] | 6
4b. [Apresentar o triângulo matriz contendo os números 7, 4 e 9] "**Qual é o número mais próximo do 7?** [Apontar para o 7] **É o 4 ou 9?**". [Apontar cada número na sua vez] | 9

5. "**Quanto é 2 mais 4?**". | 6
6. "**Quanto é 8 menos 6?**". | 2

7. [Mostrar o cartão matriz com os números 8, 5, 2 e 6, e pedir à criança para apontar e nomear cada número] "**Quando estás a contar, qual destes números tu dizes primeiro? Quando estás a contar, qual destes números tu dizes por último?**". | 2 | 8
8a. [Mostrar o cartão matriz com os números 6, 4, 2 e 9; e então perguntar:] "**Quando estás a contar de trás para a frente, qual destes números tu dizes primeiro?**". | 9
8b. "**Quando estás a contar de trás para a frente, qual destes números tu dizes por último?**". | 2

Tradução e adaptação para o Português Europeu de Joana Rato & Alexandre Castro Caldas (2012).
ICS, Universidade Católica Portuguesa. Utilização exclusiva para investigação.

TESTE DE CONHECIMENTO NUMÉRICO

(The Number Knowledge Test -NKT; Okamoto & Case, 1996)

Nível 3 (*Passagem para o nível seguinte se tiver 5 ou mais correctos*)

1. “**Quanto é 12 mais 54?**”.
2. “**Quanto é 47 menos 21?**”.

66	
26	

3a. “**Qual é o maior, 69 ou 71?**”.
3b. “**Qual é o maior, 32 ou 28?**”

71	
32	

4a. “**Qual é o menor, 27 ou 32?**”.
4b. “**Qual é o menor, 51 ou 39?**”.

27	
39	

5a. [Apresentar o triângulo matriz contendo os números 21, 25, 18] “**Qual é o número mais próximo do 21? É o 25 ou o 18?**”.
5b. [Apresentar o triângulo matriz contendo os números 28, 31 e 24]. “**Qual é o número mais próximo do 28? É o 31 ou 24?**”.

18	
31	

6. “**Qual é o número que vem 5 números depois do 49?**”.
7. “**Qual é o número que vem 4 números antes do 60?**”.

54	
56	

8a. “**Quantos números existem entre o 2 e o 6?**”.
8b. “**Quantos números existem entre o 7 e o 9?**”
8c. “**Quantos números existem entre o 3 e o 9?**”

3	
1	
5	

9a. “**Tu sabes o que é um número de 2 dígitos?**” [Se não souber, explicar.] “**Qual é o maior número de 2 dígitos?**”.
9b. “**Qual é o menor número de 2 dígitos?**”

99	
10	

10a. “**Quando estás a contar de trás para frente, qual o número que dizes primeiro, 49 ou 66?**”
10b. “**Quando estás a contar de trás para frente, qual o número que dizes por último 81 ou 69?**”

66	
69	

Nível 4

1.“Qual é o número que vem 10 números depois do 99?”
2.“Qual é o número que vem 9 números depois do 999?”
3a. “Qual a diferença maior, a diferença entre 9 e 6 ou a diferença entre 8 e 3?”
3b. “Qual a diferença maior, a diferença entre 6 e 2 ou a diferença entre 8 e 5?”
4a. “Qual a diferença menor, a diferença entre 96 e 92 ou a diferença entre 25 e 11?”
4b. “Qual a diferença menor, a diferença entre 48 e 36 ou a diferença entre 84 e 73?”
5. “Quanto é 13 mais 39?” [Mostrar o cartão].
6. “Quanto é 36 menos 18?” [Mostrar o cartão].
7. “Eu perguntei-te antes sobre os números de dois dígitos. Agora, eu quero te perguntar sobre os números de 5 dígitos. Qual é o maior número de 5 dígitos?”
8. “Quanto é 301 menos 7?”.
9. “O João levou 90 minutos para ir de casa à escola. Ele levou somente uma hora e meia para voltar da escola para casa. Podes explicar por quê?”
10a. “Qual está mais próximo de 25,35€, 20,00€ ou 30,00€?”
10b. “Qual está mais próximo de 46,45€, 46,00€ ou 47,00€?”
10c. “Qual está mais próximo de 40,00€, 29,95€ ou 68,05€?”
10d. “Qual está mais próximo 15,00€, 9,95€ ou 19,95€?”