Effects of impoverished environmental conditions on working memory performance

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Abstract

This cross-cultural study investigates the impact of background experience on four verbal and visuo-spatial working memory (WM) tasks. Eighty-four children from low income families were recruited from the following groups: (1) Portuguese immigrant children from Luxembourg impoverished in terms of language experience; (2) Brazilian children deprived in terms of scholastic background; (3) Portuguese children from Portugal with no disadvantage in either scholastic or language background. Children were matched on age, gender, fluid intelligence, and socioeconomic status and completed four simple and complex span tasks of WM and a vocabulary measure. Results indicate that despite large differences in their backgrounds and language abilities, the groups exhibited comparable performance on the visuo-spatial tasks dot matrix and odd-one-out and on the verbal simple span task digit recall. Group differences emerged on the verbal complex span task counting recall with children from Luxembourg and Portugal outperforming children from disadvantaged schools in Brazil. The study suggests that whereas contributions of prior knowledge to digit span, dot matrix, and odd-one-out are likely to be minimal, background experience can affect performance on counting recall. Implications for testing WM capacity in children growing up in poverty are discussed.

Keywords –working memory, cross-cultural, linguistic and scholastic experience, poverty.

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1. Introduction

Performance on working memory (WM) tasks has been shown to rely heavily on background knowledge and experience (Allard & Starkes, 1991; Chase & Simon, 1973; Engle & Bukstel, 1978; Gathercole, Frankish, Pickering, & Peaker, 1999; Hulme, Maughan, & Brown, 1991; Recht & Leslie, 1988). Whether poor results on WM measures reflect a global deficit in terms of capacity or a lack of experience with a given content area is therefore often difficult to establish, especially in individuals from the lower end of the socioeconomic status (SES) spectrum. This study explores different WM tasks in children from low-income families across three countries (Luxembourg, Portugal, and Brazil) in order to determine whether differential background experiences result in performance differences.

WM is a capacity limited cognitive system that maintains and manipulates information over brief periods of time, in the course of cognitive activities. It comprises mechanisms of short-term storage and processes of executive attention (Baddeley, 2000; Cowan et al., 2005; Engle, Tuholski, Laughlin, & Conway, 1999). Traditionally, WM capacity is measured by simple span tasks that primarily tap into storage, and by complex span tasks that reflect both storage and executive processes. WM tasks are generally classified as either verbal or visuo-spatial, depending on the nature of the material that has to be recalled.

Although, complex and simple span tasks have been designed to tap WM capacity it has become increasingly clear that they also rely on long-term memory support. Laboratory studies in which word lists were manipulated have shown that individuals present an advantage in recalling words over nonwords (Hulme et al., 1991) and high-wordlike over low-wordlike nonwords (Gathercole et al., 1999). Studies on expert memory indicate that individuals with a high degree of knowledge in a particular field manifest superior performance in memory recall (Allard & Starkes, 1991; Chase & Simon, 1973; Engle & Bukstel, 1978; Ericsson & Smith, 1991; Recht & Leslie, 1988). Notably, the demonstrated superiority of experts did not generalize to materials outside their domain of expertise (Ericsson & Lehmann, 1996), indicating that their exceptional memory reflects acquired skills rather than a general superiority in WM capacity per se. There are at least two ways in which prior knowledge can affect WM task performance. Firstly, elaborate knowledge structures might provide a greater opportunity for meaningful grouping of memory items (chunking), resulting in a decrease of the overall WM load of a given task (Cowan, 1997; Miller, 1956). Secondly, a stronger knowledge base of the stimulus material might increase the functional capacity of WM by enabling rapid retrieval of information in long-term memory (Chase & Ericsson, 1982; Ericsson & Kintsch, 1995). Familiarity and experience with a particular type of stimulus material can thus bias performance on standard WM tasks.

Cognitive tasks that give an unbiased estimate of an individual's WM capacity are particularly important in the light of the consistent finding that poor WM represents a high risk factor for learning disabilities (Gathercole, Pickering, Knight, & Stegman, 2004; Martinussen, Hayden, Hogg-Johnson, & Tannock, 2005; Willcutt, Pennington, Olson, Chhabildas, & Hulslander, 2005). Assessment tools that are unaffected by environmental factors are clearly desirable in order to prevent the erroneous identification of a child as presenting WM problems if in fact low performance might reflect unfamiliarity with the stimulus material. Detecting learning disabilities in children from low income families is particularly problematic (Engel de Abreu, Nikaedo et al., in press; Laing & Kamhi, 2003; Salles, Fonseca, Cruz Rodrigues, Barbosa, & Miranda, 2011), raising the need for an increase of unbiased and culture-fair assessment tools that are appropriate for exploring cognitive skills in individuals challenged by poverty.

The major aim of this study was to identify a range of WM tasks that are unaffected by environmental differences and might therefore represent good candidates for diagnostic purposes especially in the context of poverty. The paper presents a natural experiment exploring the performance of children from low-income families varying in terms of their cultural, language and scholastic backgrounds on four verbal and visuo-spatial simple and complex span tasks of WM. There is some evidence suggesting that verbal WM tasks involving numerical memoranda are relatively independent of environmental factors including SES, language, and cultural status (Engel, Santos, & Gathercole, 2008; Engel de Abreu, Baldassi, Puglisi, & Befi-Lopes, in press). It has been argued that WM tasks incorporating digits are less sensitive to long-term memory effects because they rely on item information that are sampled from a closed pool and involve familiar lexical material that is generally acquired at a young age.

The impact of environmental factors on visuo-spatial WM tasks has received less attention. As background experience affects children's language development (Noble, Norman, & Farah, 2005; Pungello, Iruka, Dotterer, Mills-Koonce, & Reznick, 2009), it is likely that performance on visuo-spatial WM tasks varies with experience because recall of visuo-spatial material has been shown to be prone to verbal recoding (Hitch, Halliday, Schaafstal, & Schraagen, 1988; Hitch, Woodin, & Baker, 1989; Miles, Morgan, Milne, & Morris, 1996). It has also been suggested that visuo-spatial tasks depend on an individual's knowledge base of geometrical structures which children acquire with schooling (Chi, 1978, Pickering, 2001; Wilson, Scott, & Power, 1987). Furthermore, visuo-spatial tasks can be affected by chunking. In one study chess masters were found to present superior memory for chess board configurations in contrast to non-expert players because they could make use of their prior knowledge to create meaningful chunks (Simon & Gilmartin, 1973).

The presented study is unique in exploring environmental effects in young children from Brazil, Portugal, and Luxembourg, who speak the same first language and were carefully matched on a range of factors including SES and fluid intelligence. Despite governmental efforts Brazil is struggling with the quality of public school education that is significantly lower than in member countries of the Organisation for Economic Co-operation and Development (OECD) (Instituto Nacional de Estudos e Pesquisas Educacionais Anísio Teixeira, 2009; Organisation for Economic Co-operation and Development, 2010). Brazilian public schools generally cope with tight budgets, teachers are often not educated past high school, and many teachers have to work several shifts in order to make a decent living (Evans & Kosec, 2012; Inter-American Development Bank, 2008). Portugal and Luxembourg are both member countries of the OECD and do not differ considerably in terms of educational quality (Engel de Abreu, Cruz-Santos, Tourinho, Martin, & Bialystok, 2012). Results on large scaled international comparison studies indicate that academic performance of public school students in Luxembourg and Portugal are comparable, whereas public school students in Brazil perform substantially worse which has been related to insufficient educational investments (Organisation for Economic Co-operation and Development, 2011). The Portuguese community represents by far the largest immigration group in Luxembourg and it has been consistently shown that Portuguese immigrant children present language weaknesses (Engel de Abreu, Baldassi, et al, in press; Engel de Abreu et al, 2012). Notably, their poor lexical development has been attributed to impoverished linguistic input rather than basic cognitive limitations.

Taken together the study compares WM task performance in three groups of children of low SES: (a) Portuguese immigrant children in Luxembourg impoverished in terms of linguistic experience; (b) monolingual children from public schools in Brazil deprived in terms of scholastic background; (c) monolingual children from Portugal with no disadvantage in either scholastic or language background. The WM measures under investigation were: digit recall and counting recall in the verbal domain; and dot matrix and odd-one-out in the visuo-spatial domain. These measures were selected because they were anticipated to minimize the impact of prior experience by using stimuli from a domain of expertise that is likely to be equally familiar to all individuals. No group differences on the WM measures were therefore expected.

2. Method

2.1. Participants

Testing was conducted in public schools across Luxembourg, Northern Portugal and two State capitals in Brazil (Salvador da Bahia and São Paulo). Caregivers completed a social background questionnaire containing information related to the development of the child, the socio-demographic characteristics of the household, and the language uses in the home. The data was collected as part of a larger study on the effects of environmental factors on children's cognitive development. Exclusion criteria included: maternal alcohol or drug use during pregnancy; severe pregnancy or birth complications; history of head injury, epilepsy, or hearing problems; stunting or wasting; severe health problems or developmental delays, special educational needs; and bilingualism (for the Portuguese and Brazilian groups). Informed written consent procedures were followed for all participants and the study was approved by the ethics committees of the University of São Paulo, the University of Luxembourg, and the University of

Minho as well as the Brazilian national commission of ethics in research (Comissão Nacional de Ética em Pesquisa).

In total 210 children from Year 2 of primary were assessed of which 67 in Luxembourg, 54 in Portugal, and 89 in Brazil. Children were matched on chronological age (range: 7 years 6 months - 8 years 7 months), gender (50% of boys in each group), fluid intelligence (Raven CPM; Raven, Court, & Raven, 1986), and the international socioeconomic index (ISEI-08; Ganzeboom, 2010). The final matched sample consisted of 84 children with an equal number of 28 children in each country. The first language of all children was Portuguese. Children from Portugal and Brazil were monolingual in Portuguese and did not study any foreign languages in school. The Portuguese immigrant group had Portugal-born caregivers who indicated speaking exclusively in Portuguese at home. All children had completed their preschool education in Luxembourg and had studied the second languages German and French in school for 19 and 4 months respectively. Schools in Luxembourg and Portugal were located in advantaged neighborhoods, did not struggle with educational resources and all teachers were trained at a bachelor or master level. The selected Brazilian schools presented a low national educational quality index (Instituto Nacional de Estudos e Pesquisas Educacionais Anísio Teixeira, 2009) and were underresourced which negatively affected their teaching quality (information obtained from teacher and school principal questionnaires).

Main participants' characteristics are reported in Table 1. Groups did not differ on the SES indexes. Caregivers across countries were low-skilled professionals (e.g. cleaners, street service workers). The Brazilian sample was ethnically more diverse, came from larger classrooms, and had completed fewer months of preschool education than children from Luxembourg and Portugal who did not differ significantly from each other.

2.2. Procedure and material

Children were tested individually, in a calm area of the school. The measures were administered in Portuguese by native Portuguese-speakers who were trained by the first author. Raw scores were used as dependent variables as no standardized norms in a population of children from Luxembourg, Portugal, or Brazil were available.

Vocabulary was assessed with the *Peabody Picture Vocabulary Test* (Dunn & Dunn, 2007) in which children have to match a spoken word to a picture out of a choice of four. The same predetermined fixed set of 64 items was administered to all children. An item analysis was conducted to classify words on the basis of their primary context being home or school (see Bialystok, Luk, Peets, & Yang, 2010 for further details). Items were classified by the first and the third author. Interrater reliability was satisfactory with a raw agreement of 94% and chance corrected agreement of .79 (Cohen's Kappa). The dependant variables were the total score on the overall test and the sub-scores in each category (home = 23 items, school = 41 items).

Working memory was evaluated with four measures from the Automated Working Memory Assessment (Alloway, 2007). All of the measures were span tasks (simple or complex) in which the number of items to be remembered increased progressively over successive blocks. The number of correctly recalled trials served as the dependent variable. In the *Digit Recall* task (verbal simple span) sequences of spoken digits have to be immediately repeated in the same order that they were presented. In the *Counting Recall* task (verbal complex span) children need to count and memorize the number of circles (4-7) in arrays containing triangles and circles. At the end of each trial the number of circles in each array has to be recalled in the correct order. Prior to administrating the task it was verified that all children could count accurately from 1 to 7. In the *Dot Matrix* task (visuo-spatial simple span) a red dot appears in different locations of a

4X4 matrix. Children need to recall the sequence of locations by tapping the squares of the empty matrix in the right order at the end of each trial. The *Odd-One-Out* (visuo-spatial complex span) contains arrays of three boxes with one abstract shape in each. Children need to identify the odd shape that does not match with the others. At the end of the trial children are presented with an array of empty boxes and are asked to recall the localization of the odd shape of each array by tapping the empty boxes in the right order.

Fluid intelligence was assessed with the *Raven Colored Progressive Matrices* (Raven, Court, & Raven, 1986) in which children need to complete geometrical figures by choosing the missing piece among 6 alternatives.

Table 1 about here

3. Results

Skew and Kurtosis for all the variables met criteria for univariate normality (Kline, 1998). Descriptive statistics including means, standard deviations, confidence intervals, and significance tests are reported in Table 1. One-way between-subjects ANOVAs indicate significant group effects on total vocabulary [F (2, 81) = 44.36, p < .01, n_p^2 = .52] and the home and school vocabulary sub-scores [F (2, 81) = 17.32, p < .01, n_p^2 = .30 and F (2, 81) = 45.85, p < .01, n_p^2 = .53 respectively]. Post hoc comparisons (Tukey HSD) showed that on total and school vocabulary all group differences were significant (p's < .05 and < .01 respectively) with the group from Portugal manifesting the highest scores and the Portuguese immigrant children manifesting the lowest scores. On the home vocabulary sub-score, the Portuguese immigrant children performed significantly worse than children from Brazil and Portugal (p < .01) who did not differ significantly from each other.

Results on the WM measures revealed no group effects on the visuo-spatial tasks dot matrix and odd-one-out and on the verbal simple span task digit recall. A significant group difference emerged on the verbal complex span task counting recall, with the Brazilian group performing significantly less well ($p < .05$) than children from Portugal and Luxembourg who did not differ significantly from each other (Tukey HSD). Zero-order correlation coefficients indicated no significant associations of vocabulary with dot matrix, odd-one-out, and digit recall for any of the groups (r's ranging from .03 to .28). Counting recall and vocabulary were not significantly linked for the groups from Portugal and Luxembourg (r's of -.10 and .26 respectively) but manifested significant associations in the Brazilian sample ($r = .55$). Multiple regression analysis indicated that, in the Brazilian group, SES and vocabulary accounted for 33% of the variance in counting recall (F (2, 25) = 6.02, $p < .01$). Notably, vocabulary ($\beta = .48$, $p < .05$) but not SES ($\beta = .18$, $p = .32$) made unique contributions to performance on counting recall. Follow up analyses indicated that school vocabulary was a better predictor of counting recall ($\beta = .44$, $p = .05$) than home vocabulary ($\beta = .15$, $p = .50$).

4. Discussion

This study explored the impact of background experience on four verbal and visuo-spatial WM tasks by comparing performance of typically developing children from low-income families in Luxembourg, Portugal, and Brazil. Notably, all children spoke Portuguese as their first language: Groups were matched on age, gender, fluid intelligence, and SES but differed in terms of cultural, scholastic, and language background. The Brazilian sample was ethnically diverse and deprived in terms of schooling: The selected schools had large student/teacher ratios, were underresourced, and of low educational quality (Instituto Nacional de Estudos e Pesquisas Educacionais Anísio Teixeira, 2009). The Portuguese immigrant children from Luxembourg presented substantial language limitations with vocabulary scores that fell more than two standard deviations below the mean of the monolingual groups from Portugal and Brazil (see also Engel de Abreu, Baldassi et al., in press).

The study clearly showed that despite large differences in their backgrounds, the groups performed equally well in the visuo-spatial WM tasks dot matrix and odd-one-out. No links with vocabulary emerged, suggesting that verbal recoding of the visual arrays was not a major factor in task performance (see Fiore, Borella, Mammarella, & De Beni, 2012; Logie, Zucco, & Baddeley, 1990 for similar findings). Whether our results can be generalized to other tests of visuo-spatial memory remains to be seen. Dot matrix and odd-one-out did not contain material that could easily be recoded into phonological form and presentation format was dynamic. There is some evidence to suggest that visuo-spatial tasks that are static provide greater opportunity for use of long-term knowledge of geometric structures which is likely to increase through schooling (Pickering, Gathercole, Hall, & Lloyd, 2001; Wilson et al., 1987). If scholastic background affects performance on static but not dynamic visuo-spatial WM tasks is clearly a subject for future studies.

The data further showed that children manifested comparable performance on the verbal simple span task digit recall. This finding is in line with previous evidence indicating that digit recall represents an unbiased and culture fair assessment tool, possibly because number words are well-known lexical items for young children irrespective of their background (Engel et al, 2008; Engel de Abreu, Baldassi et al., in press). Counter to our expectation, significant group differences emerged on the verbal complex span task counting recall, with children from Brazil performing less well than children from Portugal and Luxembourg. As no group differences were found on any other WM tasks, the Brazilians decreased performance on counting recall is unlikely to reflect a deficit in terms of WM capacity. Furthermore, it seems unlikely that their performance merely reflects weak lexical abilities as their counting recall score was even lower than the one of Portuguese immigrant children facing the challenge of learning three foreign languages and presenting severe linguistic limitations in Portuguese. A major factor that distinguished our Brazilian sample from the European groups was that children from Brazil came from disadvantaged schools. Notably, school but not home related vocabulary was significantly lower in the Brazilian group in contrast to their peers from Portugal and school vocabulary was identified as a better predictor of counting recall than home vocabulary. It seems thus valid to speculate that low scores on counting recall reflect, in part at least, reduced knowledge of counting which might be a consequence of bad schooling.

Although counting has been found to represent an effortless task in most studies involving children from advantaged educational backgrounds (Camos, Barrouillet, & Fayol, 2001; Towse & Hitch, 1997), counting might be more attentionnally demanding for children from an underprivileged scholastic background. Executive resources might thus be utilized by the need to count the circles which might deviate attention from memory storage (Barrouillet, Bernardin, & Camos, 2004). Unfortunately, examination of variations in counting speed was not possible because this variable was not measured. However, counting speed may well be an important factor to consider in future studies in order to establish weather counting was inherently more effortful or simply slower resulting in shorter retention periods (Case, Kurland, & Goldberg, 1982; Towse & Hitch, 1995).

Our result on counting recall contrasts with previous evidence indicating no significant difference between Brazilian private and public school children on the exact same measure (Engel et al. 2008). Importantly, with a total sample size of 40, Engel and colleagues (2008) did find performance differences of a medium effect size with private school children outperforming children from less advantaged schools. The authors acknowledge that with a larger sample size group differences might have reached the criterion for statistical significance. It is worth pointing out that although 28 children per group was sufficient to reveal significant effects on counting recall, our sample size was still towards the lower end and might not have been sensitive to small group differences. One of the major strengths of the study was its cross-cultural nature and its rigid matching criteria which inevitably restricted the power of the analyses.

Taken together the study suggests that the verbal WM task digit span and the visuo-spatial WM tasks dot matrix and odd-one-out are relatively unaffected by variations in life experience and might therefore provide reliable tools to explore WM capacity in individuals from socio-economically disadvantaged backgrounds. These findings have important practical implications in relation to improving the early detection of WM problems in children growing up in poverty which might contribute towards improving children's educational opportunity and future life chances.

References

Allard, F., & Starkes, J. L. (1991). Motor-skill experts in sports, dance, and other domains. In K. A. Ericsson, & J. Smith (Eds.), *Toward a general theory of expertise: Prospects and limits* (pp. 126–152). New York: Cambridge University Press.

Alloway, T. P. (2007). *Automated Working Memory Assessment*. London: Pearson Assessment.

Baddeley, A. D. (2000). The episodic buffer: a new component of working memory? *Trends in Cognitive Sciences, 4*(11), 417-423.

Barrouillet, P., Bernardin, S., & Camos, V. (2004). Time constraints and resource sharing in adults' working memory spans. *Journal of Experimental Psychology: General, 133*(1), 83-100.

Bialystok, E., Luk, G., Peets, K. F., & Yang, S. (2010). Receptive vocabulary difference in monolingual and bilingual children. *Bilingualism: Language and Cognition*, *13*(40), 525-531.

Camos, V., Barrouillet, P., & Fayol, M. (2001). Does the coordination of verbal and motor information explain the development of counting in children? *Journal of Experimental Child Psychology*, *78*(3), 240-262.

Case, R. D., Kurland, D. M., & Goldberg, J. (1982). Operational efficiency and the growth of short-term memory span. *Journal of Experimental Child Psychology, 33*(3), 386-404.

Chase, W. G., & Ericsson, K. A. (1982). Skill and working memory. In G. H. Bower (Ed.), *The psychology of learning and motivation* (Vol. 16, pp. 1-58). New York: Academic Press.

Chase, W. G., & Simon H. A. (1973). Perception in chess. *Cognitive Psychology, 4,* 55-81.

Chi, M. T. H. (1978). Knowledge structures and memory development. In R. Siegler (Ed.), *Children's thinking: What develops?* (pp.73-96). Hillsdale, NJ: Lawrence Erlbaum Associates Inc.

Cowan, N. (1997). The development of working memory. In N. Cowan (Ed.), *The development of memory in childhood (pp.163-199).* Hove, UK: Psychology Press.

Cowan, N., Elliott E. M., Saults J. S., Morey C. C., Mattox S., Hismjatullina A., & Conway A. R. A. (2005). On the capacity of attention: Its estimation and its role in working memory and cognitive aptitudes. *Cognitive Psychology, 51*(1), 42-100.

Dunn, D. M., & Dunn, L. M. (2007). *Peabody Picture Vocabulary Test, Fourth Edition*. Minneapolis: Pearson Assessment.

Engel de Abreu, P. M. J., Baldassi, M., Puglisi, M. L., & Befi-Lopes, D (in press). Cross-linguistic and cross-cultural effects on verbal working memory and vocabulary: Testing language minority children with an immigrant background. *Journal of Speech, Language, and Hearing Research.* Advance online publication (http://jslhr.asha.org/cgi/content/abstract/1092-4388_2012_12-0079v1).

Engel de Abreu, P. M. J., Cruz-Santos, A., Tourinho, C., Martin, R., & Bialystok, E. (2012). Bilingualism enriches the poor: Enhanced cognitive control in low-income minority children. *Psychological Science*, *23*(11), 1364-71

Engel de Abreu, P. M. J., Nikaedo, C., Abreu, N., Tourinho, C. J., Miranda, M. C., Bueno, O. F. A, & Martin, R. (in press). Working memory screening, school context, and socioeconomic status: An analysis of the effectiveness of the Working Memory Rating Scale in Brazil. *Journal of Attention Disorders.*

Engel, P. M. J., Santos, F. H., & Gathercole S. E. (2008). Are working memory measures free of socioeconomic influence? *Journal of Speech, Language, and Hearing Research*, *51*(6), 1580-1587.

Engle, R. W., & Bukstel, L. (1978). Memory processes among bridge players of differing expertise. *American Journal of Psychology, 91*, 673-689.

Engle, R. W., Tuholski, S. W., Laughlin, J. E., & Conway, A. R. A. (1999). Working memory, short-term memory, and general fluid intelligence: A latent-variable approach. *Journal of Experimental Psychology-General, 128*(3), 309-331.

Ericsson, K. A., & Kintsch, W. (1995). Long-term working memory. *Psychological Review, 102*(2), 211-245.

Ericsson, K. A., & Lehmann, A. C. (1996). Expert and exceptional performance: evidence of maximal adaptation to task constraints. *Annual Review of Psychology, 47*, 273-305.

Ericsson, K. A., & Smith, J. (1991). *Toward a general theory of expertise: Prospects and limits*. Cambridge, England: Cambridge. University Press

Evans, K. D., & Kosec, K (2011). Early child education: Making programs work for Brazil's most important generation. *World Bank Publications*. (http://documents.worldbank.org/curated/en/2011/06/16494500/early-child-education-making-programs-work-brazils-most-important-generation-educacao-infantile-programas-para-geracao-mais-importante-brasil)

Fiore, F., Borella E., Mammarella, I. C., & De Beni, R. (2012). Age differences in verbal and visuo-spatial working memory updating: Evidence from analysis of serial position curves. *Memory, 20*(1), 14-27.

Ganzeboom, H. B. G. (2010, May). *A new international socio-economic index (ISEI) of occupational status for the international standard classification of occupation 2008 (ISCO-08) constructed with data from the ISSP 2002-2007.* Paper presented at the Annual Conference of International Social Survey Programme, Lisbon.

Gathercole, S. E., Frankish, C. R., Pickering, S. J., & Peaker, S. (1999). Phonotactic influences on short term memory. *Journal of Experimental Psychology: Learning, Memory and Cognition*, *25*(1), 84-95.

Gathercole, S. E., Pickering, S. J., Knight, C., & Stegmann, Z. (2004). Working memory skills and educational attainment: Evidence from National Curriculum assessments at 7 and 14 years of age. *Applied Cognitive Psychology, 40*, 1-16.

Hitch, G. J., Halliday S., Schaafstal, A. M. & Schraagen J. M. (1988). Visual working memory in young children. *Memory & Cognition, 16*(2), 120-132.

Hitch, G. J., Woodin M. E., & Baker, S. (1989). Visual and phonological components of working memory in children. *Memory & Cognition, 17*(2), 175-185.

Hulme, C., Maughan, S., & Brown, G. D. A. (1991). Memory for familiar and unfamiliar words - Evidence for a long-term memory contribution to short-term memory span. *Journal of Memory and Language, 30*(6), 685-701.

Instituto Nacional de Estudos e Pesquisas Educacionais Anísio Teixeira (National institute of educational studies and research Anísio Teixeira) (2009). *IDEB - Índice de Desenvolvimento da Educação Básica* (Basic education development index). INEP. (http://ideb.inep.gov.br).

Inter-American Development Bank (2008). The quality of education in Brazil. IDB/Research Network. (http://www.iadb.org/res/laresnetwork/files/pr296proposal.pdf).

Laing, S. P., & Kamhi, A. (2003). Assessment of language and literacy in culturally and linguistically diverse populations. *Language, Speech, and Hearing Services in Schools, 34*, 44-55.

Logie, R. H., Zucco G. M., & Baddeley, A. D. (1990). Interference with visual short-term memory. *Acta Psychologica, 75*(1), 55-74.

Martinussen, R., Hayden, J., Hogg-Johnson S., & Tannock, R. (2005). A meta-analysis of working memory impairments in children with attention-deficit/hyperactivity disorder. *Journal of the American Academy of Child and Adolescent Psychiatry, 44*(4), 377-384.

Miles, C., Morgan, M. J., Milne, A. B., & Morris, E. D. M. (1996). Developmental and individual differences in visual memory span. *Current Psychology*, *15*, 53–67.

Miller, G. A. (1956). The magical number seven, plus or minus two. *The Psychological Review, 63*(2), 81-97.

Noble, K. G., Norman M. F., & Farah, M. J. (2005). Neurocognitive correlates of socioeconomic status in kindergarten children. *Developmental Science, 8*(1), 74-87.

Organisation for Economic Co-operation and Development. (2010). *Tackling inequalities in Brazil, China, India and South Africa. The role of labor market and social policies*. OECD Publishing. (http://dx.doi.org/0.1787/9789264088368-en).

Organisation for Economic Co-operation and Development. (2011). *Divided we stand. Why inequality keeps rising*. OECD Publishing. (http://dx.doi.org/10.1787/9789264119536-en).

Pickering, S. J. (2001). The development of visuo-spatial working memory. *Memory, 9*(4/5/6), 423-432.

Pickering, S. J., Gathercole, S. E., Hall, M., & Lloyd, S. A. (2001). Development of memory for pattern and path: further evidence for the fractionation of visuo-spatial memory. *Quarterly Journal of Experimental Psychology A*, *54*(2), 397-420.

Pungello, E. P., Iruka, I. U., Dotterer A. M., Mills-Koonce, R. & Reznick, J. S. (2009). The effects of socioeconomic status, race, and parenting on language development in early childhood. *Developmental Psychology, 45*(2), 544-557.

Raven, J. C., Court, J. H., & Raven, J. (1986). *Coloured progressive matrices*. London: H. K. Lewis.

Recht, D. R., & Leslie, L. (1988). Effects of prior knowledge on good and poor reader's memory of text. *Journal of Educational Psychology*, *80*(1), 16-20.

Salles, J. F., Fonseca, R. P., Cruz Rodrigues, C., Barbosa, T., & Miranda, M. C. (2011). Desenvolvimento do instrumento de avaliação neuropsicológica breve infantil NEUPSILIN-INF (Development of the child brief neuropsychological assessment battery NEUPSILIN-INF). *Psico-USF, 16*, 297-305.

Simon, H. A., & Gilmartin, K. J. (1973). A simulation of memory for chess positions. *Cognitive Psychology*, 5, 29-46.

Towse, J. N., & Hitch, G. J. (1995). Is there a relationship between task demand and storage space in tests of working memory capacity? *The Quarterly Journal of Experimental Psychology*, *48*(1), 108-124.

Towse, J. N., & Hitch, G. J. (1997). Integrating information in object counting: a role for a central coordinating process? *Cognitive Development, 12*(3), 393-422.

Willcutt, E. G., Pennington, B. F., Olson, R. K., Chhabildas, N., & Hulslander, J. (2005). Neuropsychological analyses of comorbidity between reading disability and attention deficit hyperactivity disorder: in search of the common deficit. *Developmental Neuropsychology*, *27*,(1), 35-78.

Wilson, T. L., Scott, J. H., & Power, K. G. (1987). Developmental differences in the span of visual memory for pattern. *British Journal of Developmental Psychology*, 5(3), 249–255.

Table 1

Descriptive Statistics and Significant Tests According to Group (N=84).

	Portuguese immigrants (n = 28)		Portuguese (n = 28)		Brazilians (n = 28)		Significance		
Variables	Mean (SD)	CI	Mean (SD)	CI	Mean (SD)	CI	*F or* χ^2 (2, 81)[1]	$n_p{}^2$	Contrasts
Age (months)	97.54 (2.50)	96.57, 98.51	97.68 (2.96)	96.53, 98.83	96.04 (4.79)	94.18, 97.90	1.83	.04	--
Sex (% female)	50		50		50		.00	--	--
Length of schooling (months)	55.86 (3.24)	54.60, 57.11	54.25 (7.04)	53.30, 56.91	45.29 (13.15)	40.19, 50.39	**14.25**	**.26**	**Br < (Pt I = Pt)**
Class size (number of students)	21.68 (9.88)	17.85, 25.50	22.43 (1.97)	21.66, 23.19	28.92 (6.14)	25.30, 29.49	**6.22**	**.13**	**Br > (Pt I = Pt)**
Ethnicity (%)									
Caucasian	100		100		32.1		**49.11**	--	**Br < (Pt I = Pt)**
Afro-descendant	0		0		17.9		**10.64**	--	**Br > (Pt I = Pt)**
Multiracial	0		0		50		**33.60**	--	**Br > (Pt I = Pt)**
Socioeconomic status									
ISEI[2]	35.11 (3.78)	33.64, 36.57	37.68 (6.55)	35.14, 40.22	35.36 (12.38)	30.56, 40.16	.80	.02	--
Caregiver education (years)	8.82 (3.14)	7.60, 10.04	11.00 (3.56)	9.62, 12.38	9.78 (4.23)	8.14, 11.43	2.47	.06	--
Nutritional status (z-score)3	.75 (1.23)	.27, 1.23	.80 (.98)	.42, 1.18	.97 (1.35)	.45, 1.50	.26	.01	--
Fluid intelligence									
Raven CPM	24.96 (2.89)	23.85, 26.08	25.36 (3.70)	23.92, 26.79	23.68 (2.71)	22.63, 24.73	2.20	.05	--
Vocabulary									
Total score	42.11 (6.05)	39.76, 44.45	54.46 (3.36)	53.16, 55.77	50.78 (5.33)	48.72, 52.85	**44.36**	**.52**	**Pt I < Br < Pt**
School items	23.11 (4.26)	21.45, 24.76	32.64 (2.74)	31.58, 33.70	29.53 (4.20)	27.91, 31.17	**45.85**	**.53**	**Pt I < Br < Pt**
Home items	19.00 (2.68)	17.96, 20.04	21.82 (1.31)	21.31, 22.33	21.25 (1.38)	20.72, 21.78	**17.32**	**.30**	**Pt I < (Br = Pt)**
Verbal working memory									
Digit recall	21.93 (4.76)	20.08, 23.77	23.96 (4.17)	22.35, 25.58	24.43 (4.18)	22.81, 26.05	2.58	.06	--
Counting recall	15.96 (3.51)	14.60, 17.33	17.71 (3.39)	16.40, 19.02	13.78 (3.03)	12.60, 14.96	**9.86**	**.20**	**Br < (Pt I = Pt)**
Visuo-spatial working memory									
Dot matrix	18.29 (4.27)	16.63, 19.94	20.43 (3.71)	18.99, 21.87	18.54 (3.36)	17.23, 19.84	2.67	.06	--
Odd one out	14.82 (4.30)	13.15, 16.49	15.71 (4.10)	14.12, 17.30	15.18 (4.06)	13.60, 16.75	.33	.01	--

Note: $p < .05$ are marked in boldface. CI = 95% confidence interval. Pt I = Portuguese immigrant children living in Luxembourg. Pt = Portuguese children from Portugal. Br = Brazilian children from Brazil. [1]one-way ANOVA for continuous variables and Pearson chi-square statistics for categorical variables. [2]International socioeconomic index based on caregiver occupation. [3]BMI-for-age: Body mass index was established following WHO guidelines with calibrated Plenna MEA 07400 scales, Seca 214 stadiometers, and WHO Anthroplus software (2009).