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Performance comparison between right-handers and left-handers in a Brazilian sample of the Developmental Neuropsychological Assessment

Comparação de desempenho entre destros e canhotos em uma amostra brasileira da "A Developmental Neuropsychological Assessment"

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Abstract

Studies that investigate handedness are performed in order to relate hemispheric specialization and cognitive performance. The aim of study was compare the neuropsychological performance between right-handed and left-handed children with ages from five to six years who participated in the Brazilian study of standardization of the Developmental Neuropsychological Assessment. For analysis of socio-demographic characteristics, descriptive statistics were used. To compare the mean scores between the groups, normality was tested using Analysis of Variance (one-way Anova) and the Kruskal-Wallis test. When comparing right-handed and left-handed children with typical development, left-handed children presented poorer performance on the subtests involving Attention and Executive Functioning, Language, and Learning and Memory.

Keywords: Functional laterality; Manual preference; Neuropsychology.

Resumo

Pesquisas sobre preferência manual são realizadas com o intuito de relacionar a especialização hemisférica cerebral e o desempenho cognitivo. O objetivo deste estudo foi comparar o desempenho neuropsicológico entre crianças destras e canhotas de cinco e seis anos de idade, participantes da pesquisa de normatização brasileira da Developmental Neuropsychological Assessment. *Para análise das características sociodemográficas utilizou-se estatística descritiva. Para comparação dos escores entre os grupos, foi testada a normalidade, feita a Análise de Variância (Anova one-way) e o teste Kruskal-Wallis. Ao comparar crianças destras e canhotas com desenvolvimento típico, as canhotas apresentaram pior desempenho em subtestes que envolvem Atenção e Funções Executivas, Linguagem e Aprendizado e Memória.*

Palavras-chave: *Lateralidade funcional; Preferência manual; Neuropsicologia.*

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For over a century, the relationship between the Left Hemisphere (LH) and language has been associated with the human brain hemispheric asymmetry (Arteaga & Poblano, 2008; Willems, Van der Haegen, Fisher, & Francks, 2014). In right-handed individuals, 97% present linguistic dominance in the LH and 3% in the Right Hemisphere (RH) or bilateral dominance. Among left-handed individuals, 70% present linguistic dominance in LH and 30% in the RH or bilateral dominance (Toga & Thompson, 2003).

Studies on manual preference are carried out to relate hemispheric specialization and cognitive performance (Willems et al., 2014). Hand preference begins early, between the 10th and 12th week of gestation, occurring during the same period as brain asymmetry. Initially, genetic factors predominate, but environmental factors such as greater movement of non-dominant limb can lead to reduced asymmetry (McCartney & Hepper, 1999; Teixeira & Paroli, 2000). Recently, Reissland, Aydin, Francis, and Exley (2014) showed that maternal stress between the 24th and 36th week induces increased fetal self-touching with the left limb. Thus, the process of brain lateralization could be influenced by the biochemical imbalance that maternal stress causes in the uterus.

The morphological and functional asymmetry between the hemispheres is not fully understood from the viewpoint of molecular-based genetics. In the meta-analysis conducted by Brandler et al. (2013) with 728 individuals, the Proprotein Convertase Subtilisin/Kexin type 6 (PCSK6) gene was associated with the asymmetry of the planum temporale found in dyslexia. However, the locus is not associated with hand prevalence in the general population. The authors believe that the definition of handedness is polygenic, controlled by molecular mechanisms active early in development.

Hormonal factors justify the predominance of left-handed men. The low amount of testosterone in the womb may delay the development of the left hemisphere, which may explain why the prevalence of developmental disorders occur more in men (Johnston, Shah, & Shields, 2007; Milenković, Brkić, & Belojević, 2013). In a study conducted by Hampson and Sankar (2012), saliva sampling from 180 right-handers and left-handers was used to assay levels of bioavailable testosterone in saliva along with Desoxyribunucleic Acid (DNA) genotyping to quantify the extent of the Androgen Receptor of trinucleotide Cytosine-Adenine-Guanine (AR-CAG) repeat length, a genetic marker of the capacity of the androgen receptor to respond to testosterone. They found that left-handed men presented low levels of free testosterone, while those with ambidexterity presented weak androgen receptor activity. These findings were not found in right-handed individuals. As the AR-CAG gene is located in the X chromosome, they suggested the existence of a bridge between theory and genetics that handedness would be in a locus linked to the X chromosome. These genetic and environmental influences are already expressed earlier and therefore, handedness may be present in early childhood.

The greatest moment of development of handedness occurs early in childhood and the development of pyramidal and striatal system completes at the age of 2 and the cerebellar system at the age of 5. It is important to identify handedness of the child because some tasks can suffer interference when performed and they participate in the organization of cognitive functions (Cunha, 2000). Observing the development of handedness in children may bring insights to the relationship of handedness with cognition.

Several studies exclude left-handed individuals to reduce variance of sample. However, left-handers are important when investigating the cognitive differences based on the embodied cognition approach (Willems et al., 2014). The theory explains cognitive functioning, using the body as reference. Thus, by studying the ability of lexical decision using verbs to represent manual and non-manual actions, differences in premotor cortex activation between right- and left-handed individuals were observed. The left premotor cortex was activated more than the right premotor cortex in non-manual action verbs in right-handers. The opposite occurred with left-handers (Casasanto, Williems, & Hagoort, 2010).

When investigating 50 healthy children between the ages of 8 and 10, Arteaga and Poblano (2008) found that left-handers take longer to recognize monosyllabic pseudowords and discriminate fewer trisyllabic words. The hypothesis for these results would be due to incomplete left hemispheric specialization for language and possible difficulties would include verbal fluency, decoding and language processing speed. Thus, these children, although they have no complaints related to language, belong to a group at high risk for reading and writing disorders.

Agostini and Dellatolas (2001) measured the skills for movement repetition, vocabulary, visual memory, reading words and pseudowords, and repetition of number series in right-handed and left-handed French children. They observed that right-handers performed better at tasks such as the reading of pseudowords, recognition and visual memory, picture puzzles, prosopagnosia, and phonological fluency. Right-handed boys showed slightly better performance in semantic fluency activities and coherence between hand and foot preferences. The differences in cognitive performance between right-handed and left-handed children were not significant enough to confirm cognitive superiority.

Analyzing a cohort study of 10,000 British children, Nicholls, Johnston, and Shields (2012) noted a dissociation whereby adverse birth factors affect the brain's cognitive ability, but not handedness, and by implication, brain laterality. This study demonstrated a connection between left-handedness and reduced levels of cognitive skills in vocabulary tests at the age of five.

In a meta-analysis conducted by Preslar, Kushner, Marino, and Pearce (2014), they tested the hypothesis that there would be an association between autism and laterality that would be moderated by handedness, gender, age, brain region studied and level of Autism Spectrum Disorder. They found a moderate but non-significant effect size of group on lateralization. There was no significant effect for sex and handedness.

Tsuang et al. (2011) examined the relationship between handedness and schizotypal traits in participants with a high frequency of schizophrenia in the family. The results showed that non-psychotic left-handedness, siblings of psychotic patients, presented more schizotypal traits that indicate that an atypical lateralization process may contribute to the disorder.

Using multiple regression analysis, Nettle (2003) evaluated the relationship between handedness and high skills. Surprisingly, the author found that strength of right- or left-hand preference was associated with average intellectual capacity. In other words, early definition and defined hand preference is associated with improved cognitive capacity. This may explain the higher frequency of undefined hand preference among children with developmental disorders.

Left hand preference is associated with a risk factor for head trauma (Zverev & Adeloye, 2001), intestinal parasites, asthma, suggesting immunological changes (Uslu, Dane, Uyanik, & Ayyildiz, 2010) and including the controversial association with uncertainty of sexuality in early adolescence (Zucker, Beaulieu, Bradley, Grimshaw, & Wilcox, 2001) and sexual orientation (Valenzuela, 2010).

Based on the current literature, handedness is fertile ground for further research, particularly regarding the neuropsychological aspects. The aim of this study was to compare the performance in neuropsychological tests between right-handers and left-handers in a sample of 5- to 6-year-old children with typical development.

Method

Participants

From the normative data of Brazilian validation study of the A Developmental Neuropsychological Assessment (NEPSY-II instrument) (Korkman, Kirk, & Kemp, 2007) translated by the researchers, we selected 203 children from 1,260 individuals with ages between 5 and 6 for school analysis. Hand preference was defined during training of the literacy process in the age group between 5 and 6, reason why we chose this age group (Rigal, 1992).

Instruments and Procedures

The NEPSY-II is an instrument for developmental neuropsychological assessment of children between the ages of 3 and 16. The battery is theoretically divided into six sections or Cognitive Domains: Attention/Executive Functioning, Language, Visuospatial Processing, Sensorimotor, Learning and Memory, and Social Perception (Table 1). Of the 32 subtests of the instrument, 26 are applicable to 5- to 6-year-old children and these were used in the present study (see Table 1) (II NEPSY Manual, Korkman et al., 2007). Briefly, given the complexity of the instrument, the NEPSY-II is a flexible battery that is specifically designed for children and it is not an adaptation of a test developed for adults. As an example, in the Design Copying subtest the child has to copy two-dimensional geometric pictures in increasing complexity to observe perceptual motor and visual aspects. In the Visuomotor Precision subtest, the child has to draw a line inside winding paths without touching the sides in the shortest possible time. It evaluates fine motor speed and precision.

The individual application of the battery occurred between 2010 and 2012 by a trained staff at the child's school or residence. The parents were asked to sign an informed consent form and the child agreed to participate in the study. Handedness was evaluated by an examiner, in accordance with the American NEPSY-II Clinical and Interpretive Manual, as right-handers, left-handers or undefined.

Descriptive statistics were used to analyze socio-demographic characteristics. In this stage of the study, in addition to the general analysis, the sample was divided into two groups: left-handers and right-handers. To compare the scores between the groups, the normality of sample distribution was tested using Shapiro-Wilk test, histogram normal curve, skewness and kurtosis. Analysis of Variance (one-way Anova) was used to analyze possible differences in performance between right-handers and left-handers for each subtest with normal distribution. For the subtests without normal distribution, data was analyzed using Kruskal-Wallis test. The value of $p < 0.05$ was used to define the subtests that were statistically different between the two groups. To perform the analysis of the data, the Statistical Package for Social Sciences (SPSS, version 18.0) was used.

The study was approved by the Research Ethics Committee of the *Hospital Santa Izabel*, report obtained on August 11, 2006 (*Sistema Nacional de Informação sobre Ética em Pesquisas Envolvendo Seres Humanos*, process nº 98513).

Results

Table 2 describes the socio-demographic characteristics of the sample. There is a predominance of right-handers, totaling more than 90.0% of the sample. When comparing the groups of hand preference, no statistically significant differences were found for any of the socio-demographic data. No significant percentage differences between sex and type of school were found intra-group. In both groups, a high percentage of mothers (47.5%) had 8 to 11 years of education in the left-handed group and 46.8% in the right-handed. In the right-handed sample, we observed that approximately half of the children were in each age group (5 and 6 years old), but in the left-handed group, 63.2% were 5-year-old.

Of the 32 battery subtests, four showed statistically significant differences between the two groups (right-handers x left-handers) in the domains Attention/Executive Functioning, Language and Memory. In the Attention/Executive Functioning domain, two subtests showed differences: Auditory Attention Total Comission Errors score; and Design Fluency (DF), two scores - Random Series and Total Score. In Language, the Total Score for the Word Generation (WG) subtest and Learning and Memory, the Total Score for Memory for Faces, but not for Memory for Faces Delayed.

The Auditory Attention Subtest (AARS), in the Attention and Executive Functioning domain, provides scores for the number of right answers,

Table 1
Subtest of NEPSY II for 5- to 6-year-olds

	Subtests	Aspect assessed	Abbreviation
Attention/Executive functioning	Auditory Attention and Response Set	Consists of two tasks 1. Auditory Attention: Selective auditory attention and auditory sustained attention 2. Response Set*: Alternating and auditory sustained attention and response inhibition	AARS*
	Animal Sorting	Cognitive flexibility	AS*
	Statue	Persistance and motor inhibition	ST
	Design Fluency	Visuomotor fluency	DF
	Inhibition	Inhibition of automatic responses in favor of new responses and ability to switch types of responses	IN
	Clocks	Planning and organization	CL*
Memory and learning	Word List Interference	Working and short-time verbal memory	WI*
	Narrative Memory	Semantic memory	NM
	Memory for Designs (immediate and late)	Short- and long-term non-visual memory	MD/MDD
	Memory for faces (immediate and late)	Short- and long-term memory for faces	MF/MTF
	List Memory (immediate and late)	Learning and short- and long-term verbal memory	LM/LMD*
	Memory for Names (immediate and late)	Short- and long-term memory for names	MN/MND**
	Sentence Repetition	Short-term verbal memory	SR
Language	Comprehension of Instructions	Perception, processing and performing oral instructions	CI
	Body Part Naming and Identification	Naming and identifying names. Expressive and receptive language	BP
	Speeded Naming	Speed of semantic access	SN
	Phonological Processing	Phonological awareness	PH
	Word Generation	Verbal fluency	WG
	Repetition of Nonsense Words	Phonological coding and decoding	RN
	Oromotor Sequences	Oromotor comprehension	OS
Visuospatial processing	Block Construction	Visuospacial and visiomotor abilities	BC
	Design Copying	Visuoperceptual and motor abilities	DC
	Route finding	Visuospatial orientation	RF
	Arrows	Judging line orientation	AW
	Picture puzzles	Visual discrimination, spatial localization and visual screening	PP*
	Geometric puzzles	Mental rotation, visuospatial analysis, and attention to details	GP
Sensorimotor	Imitating Hand Positions	Visuospatial analysis, motor sequencing and kinesthetic *feedback*	IH
	Visuomotor Precision	Fine motor speed and precision	VP
	Manual motor Sequences	Imitation of sequence of rhythmic motion	MM
	Fingertip Tapping	Dexterity and motor speed of fingers. Motor planning	FT
Social perception	Affect Recognition	Recognizing emotions	AR
	Theory of mind	Understanding mental functioning and the other person's point of view	TM

Note: *Subtests not used for 5- and 6-year olds; **Subtest not used to present score differences for 5- and 6-year olds.
NEPSY: Developmental Neuropsychological Assessment.

Table 2
Socio-demographic characteristics of participants

Characteristic		Right		Left	
		n	%	n	%
Total	Participants	184		19	
Gender (extra group)	Female	94	51.1	10	52.6
	Male	90	48.9	9	47.4
Age (intra group)	5 years	90	48.9	12	63.2
	6 years	94	51.1	7	36.8
School (intra sample)	Private	91	49.5	12	63.2
	Public	93	50.5	7	36.8
Mother's education[1] (years of education) - (intra sample)	0 a 3	5	2.7	1	5.3
	4 a 7	16	8.7	4	21.0
	8 a 11	86	46.8	8	47.5
	≥ 12	66	35.8	5	26.3
Socio-economic class[2] (intra sample)	A1-A2	40	21.7	1	5.3
	B1-B2	59	32.0	8	42.1
	C1-C2	63	34.2	7	36.8
	D	13	7.1	2	10.5

Note: [1]Twelve families did not disclose this information; [2]Ten families did not disclose this information.

omission errors, commission errors and inhibition errors, as well as qualitative observations (distracted behavior and moving around/getting up from the chair), in task of selective auditory attention and auditory sustained attention. The performance of left-handers was significantly lower in one of the scores (p = 0.01), as they committed more action errors than right-handers (Mean - M = 12.21, M = 6.74, respectively).

Design Fluency, in the Attention and Executive Functioning domain, is a subtest that assesses nonverbal fluency through a paper/pencil task generating original pictures, connecting five points, within a time limit. It consists of two steps: Structured Series and Random Series. In the Random Series, where the points do not follow a simple geometric pattern, left-handers presented a significantly lower performance (M = 1.98, p = 0.008). The Total Score for DF consists of the sum of scores of the Structured and Random Series. In this subtest right-handers produced more drawings than left-handers (M = 12.5, M = 9.63, p = 0.016).

In the Language domain, the WG subtest, which assesses verbal fluency within a time limit, consists of two categories (semantic and phonological). The 5- and 6-year-olds only performed the semantic category. A lower performance was found for left-handers than right-handers (M = 13.47, M = 16.91, respectively, p = 0.002).

In the Memory and Learning domain, the Memory for Faces subtest assesses encoding, discrimination and recognition of facial features, in which a number of faces must be recognized by the child. In addition, the later stage assesses long-term memory for faces. The right-handers recalled more faces in the shorter period than the left-handers (M = 8.6, M = 7.11, p = 0.045) (Table 3).

Discussion

The aim of the present study was to identify performance differences between right-handers and left-handers with typical development using NEPSY-II, a developmental neuropsychological assessment instrument. With regard to the socio-demographic variables, the frequency of left-handers (9.4%) was equivalent to the percentage described in the literature (Johnston, Nicholls, Shah, & Shields, 2010).

Table 3

Statistical and clinically significant differences between right-handers and left-handers

Domain/Subtests	Right				Left				*p*	Difference (Mean Rank)
	Mean Rank	*M*	min - max	*SD*	Mean Rank	*M*	min - max	*SD*		
Atenttion/ExecutiveFunctioning										
AA - Commission Errors (max. 180)	97.66	6.74	0 - 96	14.54	133*	12.21	0 - 38	13.5	0.010	35.34
DF Random Series (max. 35)	104.02	6.43	0 - 23	3.37	67	4.58	2 - 11	1.98	0.008	37.02
DF Total Score (max. 70)	103.68	12.50	1 - 48	6.20	70.24	9.63	6 - 20	3.06	0.016	33.44
Language										
WG Total Score	104.04	16.91	3 - 41	5.66	61.76	13.47	7 - 27	5.47	0.002	42.26
Memory and Learning										
MF (max. 16)	104.14	8.60	1 - 16	2.88	76.11	7.11	3 - 12	2.62	0.045	26.03

Note: *When the score refers to an error, the higher the mean, the poorer was performance. Kruskal-Wallis $p < 0.05$.

AA: Auditory Attention; DF: Design Fluency; *M*; Mean; MF: Memory for Faces; *SD*: Standard Deviation; WG: Word Generation.

As for hand preference associated with gender, there was no significant difference, which corroborates the studies of Arteaga and Poblano (2008), Beratis et al. (2009) and Preti et al. (2014). Other authors (Johnston et al., 2007; Milenkovi et al., 2013) found a prevalence of left-handed men. The association between sex and hand preference is still controversial. Because it is related to multifactorial inheritance, other factors may be important for handedness. Sexuality cannot be predominant in men with normal development; however, it could be so in clinical samples of developmental disorders. These disorders have genetic and/or environmental causes. The study of Pogetti, Souza, Tudella, and Teixeira (2013) exemplifies the strength of environmental factors on handedness. In that study, the authors conducted a unilateral visual occlusion and observed that there was a decrease in the use of the ipsilateral limb during and immediately after occlusion. The authors concluded that visual availability interferes with hand choice. Other factors, such as maternal stress (Reissland et al., 2014), are mentioned. Preslar et al. (2014) also found no relationship between gender and handedness.

Left-handers performed poorly in two subtests of the Attention and Executive Functioning domain, AARS and DF. In AARS, the left-handers committed more errors, showing difficulty in inhibitory control. In DF, they presented fewer drawings, indicating low visuomotor fluency. Why auditory attention, verbal fluency and design fluency is more deficient in left-handers in comparison with right-handers is difficult to explain. However, Beratis et al. (2009) showed that, when dealing with tasks that include executive functions and language, left-handers activate both hemispheres in a more balanced way than right-handers. Thus, the lower hemispheric specialization presented by left-handers could be a disadvantage in these cognitive domains. Would performing both functions cause one of them to be deficient? The deficit-attention disorder/hyperactivity disorder is the prototype of disability in attention/executive function. Are left-handed children with this disorder are more likely to have language disorders? Do left-handed children with specific language disorders have a deficiency in attention and executive function tasks? To answer these questions further studies will be needed.

The hypothesis of Arteaga and Poblano (2008) for hemispheric asymmetry development should also be emphasized. Considering the results of the subtests in the language domain, there were significant differences in verbal fluency subtest, WG. Left-handers presented a poorer performance than right-handers in the total semantic score (sum of animal, food and beverage categories) ($p = 0.002$). As well as the findings of Arteaga and Poblano (2008), in which left-handers took longer to recognize monosyllabic pseudowords and discriminated fewer trisyllabic words, the hypothesis is that incomplete hemispheric specialization may interfere with skills involving language in left-handers. Siengthai, Kritz-Silverstein, and Barrett-Connor (2008), in cross-sectional study with the elderly, found that left-handed women have lower verbal fluency than right-handers. In a longitudinal study conducted by Johnston et al. (2010), one of the tests used with right-handers and left-handers was the Memory for Digit Span Test (operating verbal and short-term memory), in which left-handers presented a poorer performance. The study suggests that other aspects of language, such as verbal memory, may be underdeveloped in left-handers.

Both Design Fluency as Word Generation are subtests that evolve time and productivity, visuomotor and semantics, respectively. It is important to note that both subtests evaluate functions in the Attention/Executive Functioning domain. In the Learning and Memory domain a difference was found for the subtest that assesses Memory for Faces (MF) ($p = 0.045$), nonverbal short-term test, in which left-handers presented the poorer result. Still referring to the study of Agostini and Dellatolas (2001), left-handers performed more poorly during the task that assessed prosopagnosia, which also involves the ability to recognize faces, as in the subtest used in the present study.

All subtests of cognitive domains that showed differences in the performance between left-handers and right-handers are related to anterior brain structures: prefrontal, premotor and temporal. This is an important finding as these structures tend to develop later.

Through the obtained results, it may be concluded that when comparing right-handers and left-handers with normal development, it was possible to find differences in performance in the subtests involving Attention and Executive Functioning, Language, and Memory and Learning, with no differences between gender, maternal education, socio-economic status and type of school. The predominance of performance differences in subtests of the Attention/Executive functioning, Language and Memory domains suggests involvement of anterior brain structures and development may be delayed. Questions can be raised from this finding: in brain development, may performance differences in these subtests disappear? If so, at what age will development compensate? What influences may these findings have on learning in and out of school? Further studies are needed to answer these questions.

The limitation of the present study was the small sample of left-handers. Since the data were taken from normative data, the frequency of left-handers was the general population. This limitation does not underestimate the value of data, since they derived from a population of individuals with normal development, participating in an extensive neuropsychological research.

Contributors

A. ASSIS, M. C. C. PRINZ, and T. MIRANDA contributed to conception and design, data analysis and interpretation and discussion of the results. N. ABREU contributed to review and approval of the final version of the article. N. ARGOLLO contributed to conception and design, data analysis and interpretation, discussion of the results, review and approval of the final version of the article.

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