Brain and Cognition 69 (2009) 116–120

Contents lists available at ScienceDirect

Brain and Cognition

journal homepage: www.elsevier.com/locate/b&c

Judgment of line orientation depends on gender, education, and type of error

Egas M. Caparelli-Dáquer [a,b,*], Ricardo Oliveira-Souza [a], Pedro F. Moreira Filho [c]

[a] Medical Neuropsychology Unit, School of Medicine Rio de Janeiro State Federal University (UNIRIO), Secretaria da 7ª Enfermaria, R. Mariz e Barros 775, Tijuca, 20270-901 Rio de Janeiro, Brazil
[b] Department of Physiology – Rio de Janeiro State University (UERJ), Rio de Janeiro, Brazil
[c] School of Medicine, Department of Clinical Medicine – Federal Fluminense University (UFF), Niterói, Brazil

ARTICLE INFO

Article history:
Accepted 3 June 2008
Available online 26 July 2008

Keywords:
Judgment of line orientation
Visuospatial
Error analysis
Gender
Education

ABSTRACT

Visuospatial tasks are particularly proficient at eliciting gender differences during neuropsychological performance. Here we tested the hypothesis that gender and education are related to different types of visuospatial errors on a task of line orientation that allowed the independent scoring of correct responses ("hits", or H) and one type of incorrect responses ("commission errors", or CE). We studied 343 volunteers of roughly comparable ages and with different levels of education. Education and gender were significantly associated with H scores, which were higher in men and in the groups with higher education. In contrast, the differences between men and women on CE depended on education. We concluded that (I) the ability to find the correct responses differs from the ability to avoid the wrong responses amidst an array of possible alternatives, and that (II) education interacts with gender to promote a stable performance on CE earlier in men than in women.

1. Introduction

Engineers and psychologists have devoted increasing attention to the issue of Human error (Reason, 1990). The concept of error exerts a considerable influence on how neuropsychological tests are interpreted, as well as on the models that are devised to account for brain–cognitive interactions in specific problem-spaces. In general, a "test score" represents the final output of the simultaneous or sequential workings of subordinate processes that must be correctly executed in the appropriate succession if the final result is to be within the "normal range" (Koechlin, Corrado, Pietrini, & Grafman, 2000). Thus, a normal test result indicates that several subordinate cognitive processes were normally performed. However, if only a few such processes fail the result will be probably "abnormal" even if the remaining subordinate goals are flawlessly accomplished. As a rule, then, the odds work against success. Another important implication of error analysis for an in-depth understanding of brain-behavior relationships as well as for the tailoring of rehabilitation programs to individual handicaps is that the qualitative analysis of errors is considerably more informative than the simple normal–abnormal dichotomy.

"Cancelation" and "odd-ball" tasks, which are widely used in the assessment of selective attention, concentration, and tactile, visuospatial and auditory perception, pertain to a family of neuropsychological tests in which a correct response must be chosen from an array of equally possible alternatives. These tests are particularly informative, because they allow the qualitative scoring of at least two different types of error: one that reflects the selection of a wrong alternative (commission errors), and the other, which indicate the miss of a correct alternative (omission errors).

Distinguishing among error types, such as the aforementioned commission-omission dissociation, bears obvious implications for test interpretation and scoring, and consequently for the understanding of the neurocognitive underpinnings of performance. There is growing evidence that the rates of omission and commission errors are differentially influenced both by biological factors, such as gender, and by individual characteristics, such as education (Marusic, Musek, & Gudjonsson, 2001). For example, the superiority of one gender over the other on the performance of certain visuospatial (Collaer & Nelson, 2002; Crucian & Berenbaum, 1998; Hiscock, Israelian, Inch, Jacek, & Hiscock-Kalil, 1995; Kimura, 1996; Lindgren & Benton, 1980; Montse, Pere, Carme, Francesc, & Eduardo, 2001) and language (Gur et al., 2000; Shaywitz et al., 1995) tasks has been clearly related to different modes of brain organization that distinguish men and women. For example, Shaywitz et al. (1995) showed that on phonological tasks, on which females usually outperform males, brain activation is lateralized to the left inferior frontal gyrus in males, whereas in females the pattern is more distributed, involving both the left and right inferior frontal gyrus. Gur et al. (2000) obtained similar results on language tasks, and additionally found that men showed bilateral activation on a task of judgment of line orientation, in contrast to women, who showed predominant activation of the right hemisphere.

* Corresponding author. Address: Dept. Medicina Geral, Escola de Medicina e Cirurgia (UNIRIO), Secretaria da 7ª Enfermaria, R. Mariz e Barros 775, Tijuca, 20270-901 Rio de Janeiro, Brazil. Fax: +55 21 22206791.
E-mail address: ecmad.rlk@terra.com.br (E.M. Caparelli-Dáquer).

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doi:10.1016/j.bandc.2008.06.001

Table 1
Sample composition and mean ages and scores for each subgroup

Gender	Grade	*n*	Mean age (SD)	Mean H (SD)	Mean CE (SD)
Female	Elem.	23	21.09 (4.48)	22.83 (6.21)	16.43 (9.22)
	High	71	20.00 (2.65)	23.13 (7.03)	16.18 (10.38)
	Grad.	100	20.16 (2.13)	26.92 (4.92)	6.31 (5.74)
	Total	194	20.21 (2.70)	25.05 (6.20)	11.12 (9.51)
Male	Elem.	25	20.56 (3.06)	26.56 (5.45)	18.40 (13.82)
	High	69	19.54 (1.16)	27.46 (4.70)	8.00 (7.41)
	Grad.	55	21.11 (3.67)	28.11 (4.88)	4.60 (4.75)
	Total	149	20.29 (2.75)	27.55 (4.89)	8.49 (9.32)
Total	Elem.	48	20.81 (3.77)	24.77 (6.06)	17.46 (11.76)
	High	140	19.77 (2.06)	25.26 (6.36)	12.15 (9.90)
	Grad.	155	20.50 (2.80)	27.34 (4.92)	5.70 (5.46)
	Total	343	20.24 (2.72)	26.13 (5.80)	9.98 (9.50)

The influence of formal education—usually indexed as the total number of years spent at school—on test performance, in turn, is particularly clear in tests of visuospatial perception (Lezak, 1995; Mazaux et al., 1995). However, due to the difficulty of recruiting adults with low schooling has made it difficult to disentangle any possible interactions between sex and education on visuospatial performance.

The literature on visual perception has largely employed tasks such as the Judgment of Line Orientation test (Benton, Sivan, Hamsher, Varney, & Spreen, 1994), in which the subject has to decide whether a given stimulus matches a target that is presented amidst a number of equally possible options. In such tasks, a detailed analysis of error type is hampered because, by design, only commission errors are rated. In the present investigation we recruited individuals who, for social reasons, did not attend elementary or high school at the usual ages (7–14 years old). This allowed us to probe the visuospatial performance of a large sample of volunteers with elementary, high school, and college degrees with similar age ranges. We specifically tested the hypothesis that different types of visuospatial errors were related to interactions between gender and education. We employed a task of judgment of line orientation because of the large gender effect on such tasks (Collaer & Nelson, 2002; Rahman & Wilson, 2003; Sanders & Ross-Field, 1987).[1]

2. Methods

2.1. Subjects

The sample (Table 1) was composed of 343 Brazilian students attending elementary or high school, or college (149 males and 194 females) who passed a brief screening for conditions that might interfere with performance, such as central acting drugs and a clinically significant neurological or psychiatric disorder. Although age ranged between 18 and 43 years, only 16 subjects (4.7%) were older than 25 (Fig. 1).

The three educational groups differed in age ($F(2,337) = 4.8$, $p = 0.009$) and gender ($\chi^2 = 7.40$, $p < 0.03$). The mean age of High School students differed significantly both from Elementary School ($p < 0.03$) and College ($p < 0.03$) students. Although statistically significant, the average difference in age between high and elementary school students did not exceed 1 year. Notwithstanding the probable negligible biological meaning of such small variation, we entered age as a covariate in all statistical computations (see statistical analyses).

Written informed consent was obtained from each participant before the experiment.

[1] Part of this study has already been reported in abstract form (Caparelli-Dáquer & Oliveira-Souza, 2004).

2.2. The lines test (lt) (Caparelli-Dáquer & Schmidt, 2000)

The test material comprised three plates (P1, P2, P3) printed in magenta on a yellow background (Fig. 2). Each plate (23.0 × 21.2 cm) had 11 columns separated by small dots disposed vertically. Each column had 11 lines (11.5 mm long each), which could be inclined right or leftward by 15°, 30°, 45°, 60° or 75°, thus allowing 10 possible angles. Straight angles were not used because preliminary observations indicated that they are much easier to pinpoint. The same observation had also been made by others (Collaer & Nelson, 2002).

The five leftmost and the five rightmost columns were grouped apart, thus dividing the plate into three vertical zones. The left and right zones were composed of five columns. The central zone contained one column only. At the top and at the bottom of each column a line inside a circle served as the matching stimulus for that column. Each column contained from 2 to 4 correct answers.

2.3. Procedure and scoring

The task consisted in canceling, every line that matched the stimulus line at the top and bottom of each column. Subjects were asked to start at the central column and proceed in any sequence until all columns were done. Subjects were allowed 3 min for each plate and instructed to work as quickly as possible while avoiding making mistakes. They were warned when the first and second minutes had elapsed. When the 3-min limit was reached, subjects were asked to lay down the pen and turn down the page. Before proceeding to the next plate, they were reminded of the instructions. The test was preceded by a brief practice session, which consisted of easier angles and a smaller array of five rows and five columns with two columns. The number of hits (H—*i.e.*, number of lines matching the stimulus that were canceled) and the number of commission errors (CE—*i.e.*, number of lines NOT matching the stimulus that were canceled) were computed for each plate and used as the main final scores of the test and as dependent variables for statistical analyses. Omissions (number of lines matching the stimulus but not canceled out) were not considered as a score in this study. Inasmuch as every subject completed all the trials, the number of trials and of lines matching the stimulus was equal for every subject. Therefore, the amount of lines matching the stimulus minus the number of hits equals the number of omissions for every subject, what makes omission and hits identical scores (omission and hits are a linear transformation of each other according to the following equation: lines matching the stimulus = omission + hits).

2.4. Statistical analyses

All results are summarized as means and standard error of the mean ($x \pm$ sem). Associations between categorical variables were assessed with the χ^2 test. The effects of gender and education on test performance were evaluated with two-way (2 × 3) multivariate analyses of covariance (mancova) entering age as a covariate. The multivariate approach was chosen because H and CE were moderately correlated and to reduce the probability of type I errors (Tabachnick & Fidell, 1996). Whenever an overall significant result was found, *post hoc* comparisons were performed with Fisher's least-significant-difference (lsd) test. Pearson's regression was used to analyze interactions between the two dependent variables (H and CE). Wilk's λ can vary between 0 and 1, indicating absent (0) to maximum (1) discriminant power of the variable being examined. The two-week longitudinal reliability of lt was assessed in 20 individuals with Cronbach's alpha (α). A significance threshold of 0.05, two-tailed, was set for all tests.