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PERFORMANCE OF UNIVERSITY STUDENTS ON RANDOM NUMBER GENERATION AT DIFFERENT RATES TO EVALUATE EXECUTIVE FUNCTIONS

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ABSTRACT - *Objective:* To evaluate the performance of adult young subjects in a Random Number Generation (RNG) task by controlling the response speed (RS). *Method:* Sixty-nine university students of both sexes took part in the experiment (25.05 ± 6.71 year-old). Participants were alloted into 3 groups which differed in RS rates to generate numbers: 1, 2 and 4 seconds to generate each number. A digital metronomer was used to control RS. Participants were asked to generate 100 numbers. The responses were mensured through Evans's RNG Index. *Results:* There were statistically significant differences among the groups [F (3, 68) = 7.120; p < .05]. Differences were localized between 1 and 2 seconds (p = 0.004) and between 1 and 4 seconds (p = 0.006). No differences were observed between 2 and 4 seconds (p = 0.985). *Conclusion:* The present results suggest that the response speed in production of random numbers influences the performance of the Random Numbers Generation task.

KEY WORDS: executive functions, working memory, central executive, random number generation, neuropsychological test.

Desempenho de estudantes universitários na geração aleatória de números para avaliar as funções executivas

RESUMO - *Objetivo:* Avaliar o desempenho de sujeitos adultos na Geração Aleatória de Números (RNG), em função da velocidade da resposta (VR). *Método:* Participaram do experimento 69 universitários, de ambos os sexos. A média de idade dos participantes foi 25,05±6,71 anos. Os participantes foram divididos aleatoriamente em 3 grupos que diferiram quanto à VR para gerar cada número; 1, 2 e 4 segundos. As respostas foram avaliadas através do índice RNG de Evans. *Resultados:* A análise dos resultados evidenciou diferença estatisticamente significante entre os 3 grupos [F (3, 68) = 7,120; p < 0,05], com diferenças entre as VR de 1 e 2 segundos (p = 0,004) e de 1 e 4 segundos (p = 0,006). Não foram observadas diferenças entre as VR de 2 e 4 segundos (p = 0,985). *Conclusão:* Os resultados mostraram que a velocidade da resposta na produção dos números aleatórios influencia o desempenho da tarefa de Geração Aleatória de Números.

PALAVRAS-CHAVE: funções executivas, memória operacional, executivo central, geração aleatória de números, teste neuropsicológico.

The task of random numbers generation (RNG) is a brief and efficient measure of executive functions and a clinically useful tool to assess frontal lobes disturbances[1]. The executive functions (EF) concept comprises a number of cognitive functions demanding attention, concentration, selection of stimuli, abstraction skill, planning, conceptual flexibility, self-control, and the central executive of working memory. The RNG consists of the production of numbers at random, within a given time interval. For accomplishing the task the subject needs to handle the information in real time, supress patterns of habitual or stereotyped responses, generate new responses, and monitor and change response production strategies. Human beings feel difficult to generate sequences which match hazard criteria. Generally, these difficulties are deemed to misconceptions of randomness or to malfunction of cognitive operations involved with RNG.

Several clinical and experimental trials used RNG for assessing psychiatric and neurological patients[2,3], as well as patients with brain demage[4] and with Alzheimer type dementia. According to Spatt & Goldenberg[6], differences of RNG performance between pathologic and healthy subjects are prob-

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ably due to the influence of three factors: (a) usage of previously learned schemes; (b) usage of a wrong concept of randomness; (c) difficulty or limitation for monitoring response redundancies.

RNG is also used together with neuroimaging and transcranial magnetic stimulation techniques for assessing frontal lobe integrity and functions. Such studies have revealed that the pre-frontal dorsolateral cortex (PFDLC) is involved with random sequences generation[7,8]. Artiges et al.[9] have suggested that dysfunction at the cyngulus region and at the parietal region cause losses on the working memory control processes during the RNG task course in schizophrenic patients.

The purpose of the present study was compare the performance of healthy young subjects in generating random numbers sequences at different response speeds. It is expected that the task difficulty is increased by faster response rates.

METHOD

Subjects - Sixty-nine university students, both genders, recruited in the Medicine School of Mato Grosso Federal University participated in this study. All of them signed a Consent Term previously approved by the Ethics Committee of UNIFESP before their admission to the study. Table 1 shows the main characteristics of the sample.

Procedures - The population was allocated at random to three groups of 23 subjects each, which where different in their response speed (RS). In the groups RNG1, RNG2, and RNG4, RS rates were 1, 2, and 4 seconds, respectively.

Before starting the RNG task, the following instruction was read and discussed with the participant: "When the alarm sounds, start speaking numbers aloud. You have only to repeat numbers in an aleatory (at random) way, from 1 to 10. For example, if you throw the dice several times, each one of the six numbers will appear forming a chance sequence. Your task is imagining a 10-sided dice. Tell the numbers at random. Avoid a defined sequence as, for example 3, 4, 5, 6 or 9, 8, 7 or 3, 6, 9, etc. Remember of using all the numbers, from 1 to 10". They were asked to generate 100 numbers. Their responses were annotated on a sheet of paper. A digital metronomer Seiko, model DM-33 was used. The device was adjusted to produce a sound alarm at varied frequencies of 1, 2 and 4 seconds. Participants from the three groups were asked to try generating random numbers according to the speed of the device alarm sound. The score was attributed through Evans[10] RNG Subjective Randomness Index. RNG Index is a measure which is sensitive to the randomness distance (it reflects the disproportion by which a number follows another number), in a series of 100 answers, with a scale ranging from 0.0 to 1.0. A higher index means a higher distance of the expected values, i.e. it means a poorer randomness.

RESULTS

Ages of the sixty-nine university students ranged from 17 to 43 years old, with a mean of 25.05 years and standard deviation of 6.71 years. The groups did not differ significantly by age [$F(3, 68) = 1.706$; $p > 0.05$] and gender [$F(3, 68) = 0.000$; $p > 0.05$]. Forty-nine subjects were female (71%) and the remaining 20 were male (29%) (Table 1).

RNG1 group scored an RNG Index average 0.341 with standard deviation 0.044; RNG2 group scored an RNG Index average 0.302 with standard deviation 0.034 and RNG4 group scored an RNG Index average 0.304 with standard deviation 0.038. Results were undergone to inferential statistical analysis. The alpha level 0.05 was used in all the statistical tests.

Analysis of variance (ANOVA) for the RS means of the three groups evidenced statistically significant differences between the three groups [$F(3, 68) = 7.120$; $p = 0.002$]. A post hoc analysis (Tukey Test) showed that differences occurred between RS of 1 and 2 seconds ($p = 0.004$) and between 1 and 4 seconds ($p = 0.006$). Differences were not observed in RS between 2 and 4 seconds ($p = 0.985$), as is shown in Table 2.

DISCUSSION

The results achieved in the experiment confirm the assumption that RS of random numbers generation influence the RNG task performance. In healthy adult subjects with high level of education, RNG performance was lower with increased rates of responses.

RNG1 group, which has generated aleatory numbers in a rate of one number per second, had a worse performance than RNG2 group (2 seconds) and RNG4 (4 seconds). With these results, it is possible to state that the RNG task a rate of 1 number per second is suitable as a marker of EF integrity. Patients impaired at this rate may be tested at slower rates as a mean of evaluation of the magnitude of impairment.

Table 1. Sample demographic characteristics.

	RNG1	RNG2	RNG4
Age mean (SD)	24.2 (4.9)	23.7 (7.1)	27.1 (7.5)
Gender (M/F)	11/12	7/16	2/21
Total	23	23	23

RNG, Randon Number Generation task by controlling the response speed (RS) to generate numbers: 1 (RNG1), 2 (RNG2) and 4 (RNG4) seconds; SD, Standard Deviation; M, male; F, female.

Table 2. Post hoc analysis (Tukey Test).

Groups	Difference	p
RNG1 x RNG2	0.038*	0.004
RNG1 x RNG4	0.038*	0.006
RNG2 x RNG4	-0.001	0.985

RNG, Randon Number Generation task by controlling the response speed (RS) to generate numbers: 1 (RNG1), 2 (RNG2) and 4 (RNG4) seconds; *, p < .05.

These findings confirm studies in the literature which state that RS is a critical factor of the RNG task. According to Vandierendonc[11], RS control is important since it allows a better empirical control on RNG. For Towse[12], RNG is strongly affected by RS. In our investigation, faster RS led to more stereotyped responses.

Several models try to explain how human beings elaborate the choice of numbers in random sequences. Treisman & Fulker[13], state that an inner source produces a random variable, which may be represented as an "aleatory decision axis". The subject uses measures produced by this generator for selecting random responses. The mechanism of response choice is based on decision criteria, whose position at the "aleatory decision axis" is determined by matching a theory of positioning and maintaining criteria, which were previously defined by the subject. These authors have conceived as cognitive intrusion the mechanism of interference on the selection system of responses during the RNG performing. The Rabinowitz et al.[14] model is based on mathematical rules. These authors sustain that the subjective conception of the subject's randomness, instead of memory or attention, is primarily more important in the generation of aleatory sequences. They based their theory on experimental investigation of both adults and children. They have compared the performance of 1st, 5th degree students and adults in the RNG task. The results have pointed out that the rules used by subjects changed according to their ages.

Jahanshahi et al.[15] have proposed the net modulation pattern, based on their investigations with neuroimaging techniques. The net modulation pattern says that the suppression of usual responses, the key process for generating random responses, is reached by modulation (inhibitory) of left pre-frontal dorsolateral cortex, which exerts an influence on the associative network of the superior temporal cortex. Baddeley et al.[16] model relates the generation of aleatory sequences with the central executive component of working memory. RNG task is a procedure demanding the central executive processing without the aid of phonological and visual-spatial processing.

Our results may be attributed, according to Jahanshahi et al.[15], to greater difficulties in the suppression of the usual responses, due to a higher need of inhibitory modulation of the left pre-frontal dorsolateral cortex in the associative network of numbers generated at fast rate. For Baddeley et al.[16], the RS effect on RNG may be attributed to a higher load on the central executive processing in order to handle the generation of random sequences at this rate.

Finally, we believe that RNG is a useful measure for clinical practice and for experimental research to investigate EF. However, further studies with different age groups, education all levels, and pathological conditions are needed.

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