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. 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, suppress 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, as well as patients with brain damage and with Alzheimer type dementia. According to Spatt & Goldenberg, differences of RNG performance between pathologic and healthy subjects are probable.
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. Artiges et al. have suggested that dysfunction at the cingulus 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 chronometer 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 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.

<table>
<thead>
<tr>
<th></th>
<th>RNG1</th>
<th>RNG2</th>
<th>RNG4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age mean (SD)</td>
<td>24.2 (4.9)</td>
<td>23.7 (7.1)</td>
<td>27.1 (7.5)</td>
</tr>
<tr>
<td>Gender (M/F)</td>
<td>11/12</td>
<td>7/16</td>
<td>2/21</td>
</tr>
<tr>
<td>Total</td>
<td>23</td>
<td>23</td>
<td>23</td>
</tr>
</tbody>
</table>

RNG, Random 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.
which state that RS is a critical factor of the RNG
the subjective conception of the subject’s ran-
on mathematical rules. These authors sustain that
They have compared the performance of 1st, 5th
mental investigation of both adults and children.
ry sequences. They based their theor y on experi-
marily more important in the generation of aleato-
domness, instead of memory or attention, is pri-
results have pointed out that the rules used by sub-

Several models try to explain how human be-
ings elaborate the choice of numbers in random
sequences. Treisman & Fulker13, 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, who-
se position at the “aleatory decision axis” is deter-
mained by matching a theory of positioning and
maintaining criteria, which were previously defined
by the subject. These authors have conceived as cog-
nitive 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 ran-
domness, instead of memory or attention, is pri-
marily more important in the generation of aleatory
sequences. They based their theory on experi-
mental 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 sub-
jects changed according to their ages.

Jahanshahi et al.15 have proposed the net mo-
dulation pattern, based on their investigations
with neuroimaging techniques. The net modula-
tion 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 mem-
ory. RNG task is a procedure demanding the cen-
tral executive processing without the aid of pho-
nological and visual-spatial processing.

Our results may be attributed, according to Ja-
hanshahi et al.15, to greater difficulties in the sup-
pression of the usual responses, due to a higher
need of inhibitory modulation of the left pre-front-
al 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 se-
quen ces at this rate.

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

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Table 2. Post hoc analysis (Tukey Test).

<table>
<thead>
<tr>
<th>Groups</th>
<th>Difference</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>RNG1 x RNG2</td>
<td>0.038*</td>
<td>0.004</td>
</tr>
<tr>
<td>RNG1 x RNG4</td>
<td>0.038*</td>
<td>0.006</td>
</tr>
<tr>
<td>RNG2 x RNG4</td>
<td>-0.001</td>
<td>0.985</td>
</tr>
</tbody>
</table>

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