Cardiovascular Response to Stroop Test: Comparison between the Computerized and Verbal Tests

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Abstract

Background: **The Stroop test requires the individual to respond to specific elements of a stimulus, whereas inhibiting more automated processes.**

Objective: **To compare the cardiovascular reactivity induced by the computerized version of the Stroop word-color test TESTINPACS™ with the traditional version based on the reading of printed words.**

Methods: **The sample of convenience consisted of 20 women (22.4 ± 4.1 years). Analyses of variance with repeated measures were used to compare the main effects between the tests (computerized *vs* verbal), as well as between phases of the test (baseline, Stroop 1, Stroop 3) on the physiological variables (arterial pressure, respiratory sinus arrhythmia, heart failure and respiratory rate). The *t* tests for paired samples were used to compare the pressure means between Stroop 3 and baseline. Additionally, the magnitude of the effects (*d'*) was estimated in order to assess the impact of the changes in the physiological measurements between Stroop 3 and the baseline.**

Results: **The two versions of the assessment tool caused significant increase in heart rate (p<0.01) and systolic arterial pressure (p<0.05) when the measurements obtained at the Stroop 3 were compared to that of baseline. However, no significant differences were observed regarding the different versions of the test on the other investigated variables. The *d'* statistics confirmed the high magnitude of the effects (-1.04 to +1.49) between the measurements from the Stroop 3 and the baseline ones.**

Conclusion: **It is concluded that the current computerized version (TESTINPACS™) of the Stroop test constitutes a useful instrument to induce cardiovascular reactivity in women. (Arq Bras Cardiol 2010; 94(4):477-481)**

Key words: **Stroop test; stress, psychological; cardiovascular reactivity; Brazil.**

Introduction

The hypothesis that psychological factors have an influence on the onset of diseases, as well as on their course, is an old one. Recently, one of the main areas in psychosomatic research has investigated the effects of mental or emotional stress on cardiovascular reactivity[1]. According to the experimental and epidemiological data, the mental stress is a contributing factor to the morbimortality due to cardiovascular etiology, particularly the hypertensive and the coronary types[2-5].

In this sense, methods of investigation that induce cardiovascular reactivity can present potential applicability in the identification and/or stratification of cardiovascular risk, justifying studies aiming at the standardization of these methods[4,6,7]. Thus, the Stroop Word-Color Interference test has been used as a laboratory stressor and promising instrument of clinical use[8]. Briefly, it consists in a set of stimuli with words printed in a single color and that form the name of another color, for instance: the word "blue" printed in green color. When the participant is asked to answer on the color of the word and ignore its identity (the word-color interference effect), the automatic processing of the word identity is inhibited due to less automated processes, such as the color used to print the word. Physiological and response latency variables are commonly used to estimate the effects of the contextual interference[9].

There is no description in Brazil of a software in Brazilian Portuguese for the investigation of Stroop paradigm. Considering that computer technologies provide a higher degree of accuracy for the measurement and control of presentation of stimuli[10] in comparison with pencil-and-paper based tests, the objective of the study was to compare the cardiovascular reactivity induced by the computerized version of the Stroop word-color test TESTINPACS™ with the verbal version, i.e., based on the reading of lists of words.

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Manuscript received on August 31, 2009; revised manuscript received on September 28, 2009; accepted on October 9, 2009.

Measurements of arterial pressure, respiratory sinus arrhythmia, heart and respiratory rate were used to evaluate the effects of the acute psychological stress.

Methods

Participants

Initially, a pilot study was carried out (n=10) with the purpose of investigating the effect size, considering the level of significance (α=5%) and the test power (1-β) in 80% in a paired *t* test with bilateral hypotheses for the main dependent variable: systolic arterial pressure (SAP). Still in this phase, the results of the statistics suggested significant differences. Therefore, it was deemed unnecessary to calculate the sample dimension.

A convenience sample consisting of 26 female university students was used in the study. The following aspects were used as exclusion criteria: a) impossibility to complete the test; b) report of cardiorespiratory problems; c) sight or hearing problems without the possibility of correction; d) use of drugs that could impair the cognitive functions; and e) report of prior participation in a Stroop test. Of the total number of participants, six volunteers were excluded due to some of the aforementioned criteria. Thus, the sample consisted of 20 participants aged from 18 to 27 years (22.4 ± 4.1 years). All participants were advised not to smoke or ingest any food, caffeine or alcohol in the two hours prior to the test. Since each participant was her own control, it was presumed that the study design suppressed potential confounding factors related to the hormonal influences caused, for instance, by the menstrual cycle on the emotional responses. The study was approved by the Ethics Committee in Research of the institution according to the Declaration of Helsinki.

General procedures

Computerized test - TESTINPACS™. A 17-inch color monitor was placed at the level of the participants' eyes at a distance of approximately 80 cm. In Stroop 1, rectangles (2.0 cm x 2.5 cm) in the following colors: green, blue, black and red were presented individually, in the center of the monitor. At the lower corners of the monitor, responses corresponding or not to the color of the rectangle were exhibited until the participant responded to the attempt by pressing the keys (←) or (→) in a standard keyboard. In the second phase, Stroop 2, both stimuli and the responses were exhibited as words, always in white. The correct answer was considered when there was a coincidence between stimulus and response. Finally, in the last phase, Stroop 3, the name of one of the four colors was exhibited in an incompatible color. At this phase, the participant was instructed to press the key corresponding to the color of the letters and inhibit the response for the identity of the disclosed word. At all phases, the stimuli were presented randomly (12 attempts/phase) and the time was registered in milliseconds[10].

Verbal test - Lists of words were printed in an A-4 paper size sheet and randomly organized in a central column. In Stroop 1, rectangles in the following colors: green, red, yellow and blue were exhibited and the colors were rapidly identified. At the second phase, Stroop 2, the words with the names of the colors were printed in black and the participants were instructed to read the words. At the last phase, Stroop 3, colors that were incompatible with the words were exhibited and the participants were instructed to state, verbally, the color of the words as fast as possible. The time spent in each phase of the test[10] was measured with a precision of centesimal seconds using a digital chronometer (T-20 model, Sigma-Aldreich). All tests were carried out in a laboratory free of external sound interference.

The order of test presentation was controlled, so that half of the participants started with the computerized version and the other half, with the verbal test. To stabilize the physiological measurements, the participants were asked to remain comfortably seated on a chair for 10 minutes. Baseline measurements were acquired from the 10th minute of rest onwards. Except for the pressure measurements, where the second collection coincided with the end of Stroop 3, the other signs were acquired continuously until the end of Stroop 3. Bioelectrical signs were acquired in individuals channels and digitized through an Analogical/Digital converter with 12 bits (BIOPAC Systems, St. Monica - USA). The sampling frequency was established at 250 Hz and the signs were stored in a PC for offline analyses. To attenuate interferences, a 60-Hz Notch filter was used. All recordings were assessed by a cardiologist with the objective of identifying arrhythmias and/or movement artifacts. The temperature of the laboratory was maintained between 23 and 24°C. The experiments were carried out between 2 PM and 5 PM.

Physiological measurements

Heart rate - To monitor the ECG, the positive electrode was positioned below the lowest palpable rib on the left hemiclavicular line and the negative electrode was positioned below the right clavicle - derivation II. Before the cables and electrodes were fixed on the skin, the latter was slightly scrubbed with alcohol-soaked gauze. R-R intervals were calculated as the temporal difference between consecutive peaks of voltage, whereas the heart rate (HR) was estimated based on the R-R intervals.

Respiratory rate - A pneumograph stretch transducer adjusted around 7 cm above the umbilicus was used. The analogical outlet for the respirogram was differentiated for a series of rectangular impulses, digitized at real-time, to assess the respiratory rate (RR) in cycles per minute.

Respiratory sinus arrhythmia - It was quantified in the field of the temporal domain from the peak-valley algorithm described by Paso et al[11]. Measurements of the respiratory sinus arrhythmia (RSA) were calculated for the respiratory cycles of the participants (n=17) using typical rate intervals of 0.15 to 0.33 Hz (9 to 20 respirations. min^{-1}, respectively). The analyses were carried out when the fluctuations between the heartbeats were clearly associated with the respective phases of the respiratory cycles. Some reasons justified the inclusion of this measurement: a) it provides the assessment of the parasympathetic activity as the underlying mechanism for the regulation of physiological responses associated to mental stress[12]; b) it presents an almost perfect correlation with the measurements of the parasympathetic component in the frequency domain[13].

Arterial pressure - The non-invasive measurement was carried out using an Omron automatic digital sphygmomanometer (model HEM - 742INT, Omron, Bannockburn, IL). The baseline arterial pressure (AP) was estimated based on three measurements performed at 5-minute intervals at rest. For the measurement, the participant remained seated and the left arm was extended with the cuff placed at the heart level.

Statistical analysis

Analyses of variance (ANOVA) with repeated measures were used to verify the main and interaction effects for the factors: Tests (computerized *versus* verbal) and Phases (baseline, Stroop 1, Stroop 3). The dependent variables HR, RR and RSA were analyzed separately. Measurements corresponding to Stroop 2 were not analyzed as they constituted exclusively a preparatory phase for Stroop 3. When significant differences were observed, Bonferroni test for multiple comparisons, with adjustments for the level of significance of $p < 0.05$, was used. The *t* tests for paired samples were used to compare the means of AP between baseline and Stroop 3. The magnitude of the effects (*d'*) was estimated to assess the impact of the changes in the physiological measurements between Stroop 3 and the baseline. According to Cohen's convention[14], effects of approximately (0.20) are considered low, (0.50) are considered medium and (0.80) are considered high. The data are presented as means ± standard deviations.

Results

The results suggest that the two versions significantly increased HR ($p<0.01$) and systolic arterial pressure ($p<0.05$) when the outcomes of the Stroop 3 were compared to the baseline measurements (Table 1). No significant difference was observed, however, regarding the measurements of AP, HR and RSA between the versions.

The *d'* statistics showed that the magnitude of the effects varied between - 1.04 to + 1.49 (Table 2), which suggests, according to Cohen's convention[14], a high effect between measurements related to Stroop 3 and the baseline. It is noteworthy that the recordings of three participants were excluded due to the presence of artifacts, possibly due to the irregularity of the respiratory movement profile presented by the participant and/or the position of the pneumograph transducer at the moment of the recording.

Discussion

The objective of the study was to compare the cardiovascular reactivity induced by the computerized version of the Stroop word-color test - TESTINPACS™ - against the verbal version. The results of the physiological measurements suggest that the computerized version is a useful tool to induce cardiovascular responses due to acute mental stress in women. It was verified during the Stroop 3 phase that the computerized and verbal versions result in increases of the same magnitude in variables such as HR, for instance, in relation to the baseline measurements (21.5% *versus* 21.3%, respectively). In turn, the *d'* statistics showed that the effects of the mental stress resulted in high variations in HR (1.44 to 1.49). These results can be attributed, at least in part, to the sympathetic neurohumoral activation due to the information processing demand to the effects of the word-color interference. Although the present study assessed normotensive women (SAP < 140 mmHg /

Table 2 - **Measurements of reactivity (Δ) and magnitude of the effect (*d'*) between the baseline and the Stroop 3 for the computerized and verbal versions of the Stroop test**

Parameters	Computerized		Verbal	
	Δ (delta)	d'	Δ (delta)	d'
HR (n = 20)	21.30	1.44	21.00	1.49
RR (n = 17)	0.20	0.07	2.00	1.49
RSA (n =17)	-48.80	-1.04	-17.50	-0.26
SAP (n =20)	12.90	1.42	12.40	1.46
DAP (n =20)	0.40	0.04	-4.50	-0.41
MAP (n =20)	6.70	0.89	4.50	0.63

HR + heart rate in beats per minute; RR - respiratory rate in cycles per minute; RSA - respiratory sinus arrhythmia in milliseconds; SAP - systolic arterial pressure in mmHg; DAP - diastolic arterial pressure in mmHg; MAP - mean arterial pressure in mmHg; d' - statistics estimated from Cohen's equation[14], $[(x_1 - \bar{x}_2)/\sigma_{\bar{x}}]$.

Table 1 - **Comparison of the parameters between the computerized and verbal Stroop tests (mean ± standard deviations)**

Parameters	Base line	Computerized		Verbal	
		Stroop 1	Stroop 3	Stroop 1	Stroop 3
HR (n =20)	77.6 ± 1.9	87.1 ± 2.0†	98.9 ± 4.7*	91.6 ± 4.9†	98.6 ± 4.4*
RR (n = 17)	16.1 ± 0.3	15.3 ± 1.6	16.3 ± 0.9	12.0 ± 1.7*	18.1 ± 0.3 ‡
RSA (n = 17)	83.9 ± 15.5	49.7 ±7.3	35.1 ± 7.3	66.7 ± 13.9	66.4 ± 17.4
SAP (n = 20)	118.3 ± 1.9	-	131.2 ± 2.8‡	-	130.7 ± 2.5‡
DAP (n = 20)	73.6 ± 2.1	-	74.0 ± 3.0	-	69.1 ± 3.5
MAP (n = 20)	95.9 ± 1.2	-	102.6 ± 2.7	-	100.4 ± 2.5

HR - heart rate in beats per minute; RR - respiratory rate in cycles per minute; RSA - respiratory sinus arrhythmia in milliseconds; SAP - systolic arterial pressure in mmHg; DAP - diastolic arterial pressure in mmHg; MAP - mean arterial pressure in mmHg; d' - statistics estimated from Cohen's equation[14], $[(\bar{x}_1 - \bar{x}_2)/\sigma_{\bar{x}}]$. (*) - significant difference (p<0.01) versus baseline; (†) - significant difference (p=0.01) versus baseline; (‡) - significant difference (p<0.05) versus baseline.

DAP < 90), in accordance with the criteria of classification in the V Brazilian Guidelines of Arterial Hypertension[15], clinical trial results emphasize the diagnostic and predictive value of the HR. For instance, there have been reports of increased HR and cardiac output in young individuals with hyperkinetic circulation, although the peripheral vascular resistance remains within normal intervals[6].

Considering that the cardiovascular reactivity in a situation of mental stress is not an exclusive reflex of the degree of sympathetic activity[11], it is possible that the decrease in the vagal activity, expressed in the RSA measurements, contributed to the increase observed in HR during the Stroop 3 phase. According to Porges[16], activities that demand high levels of mental stress and attention processing can result in the decrease of the parasympathetic tonus and homeostatic alterations. In fact, it was verified that in the computerized and verbal versions, the participants decreased RSA (58.2% *versus* 20.9%, respectively). However, it is probable that the high data dispersion in relation to the means within the groups (Table 1) decreased the test power and, consequently, the probability of observing significant differences in relation to the baseline measurements. Nevertheless, these results corroborate other studies[6,11] in which complex interactions between the sympathetic-parasympathetic systems occur when the participants are submitted to tests that demand states of attention and acute psychological stress.

The results on the RR measurements were particularly interesting. As expected, only the verbal version presented significant differences in relation to the baseline measurements. At the Stroop 3 phase, the participants showed an increase in RR of around 11.0% in relation to the baseline. In turn, at the Stroop 1 phase, this variable showed a decreased of approximately 25.5%. Considered together, these results seem to reflect a specific pattern of behavior. For instance, considering the easiness of responses in the absence of word-color interference effects (Stroop 1), it is probable that the participants with the objective of finishing the phase quickly performed a longer inspiration followed by a brief voluntary respiratory pause. This maneuver, in the beginning of the test, can justify the significant decrease in the RR.

The results also suggest that the conflict generated by the word-color interference significantly increased SAP in both the computerized an verbal versions (9.5% *versus* 9.8%, respectively). The high magnitude of the effects (*d'*) reflects these results (1.42 *versus* 1.46, respectively). Measurements of AP are extremely relevant in clinical practice. According to the hypothesis of cardiovascular reactivity, individuals that exhibit pressure responses much above the normal range in the presence of stressing environmental stimuli, present a potential risk for the development of cardiovascular diseases, particularly the hypertensive and the coronary types[17].

In this sense, tests that induce mental stress can contribute to the early detection of pressure hyper-reactivity in individuals with a potential predisposition to hypertensive disease. The results, however, did not disclose significant differences in the MAP measurements. Nevertheless, it is probable that these results are the result of the small variation observed in the diastolic arterial pressure (DAP) of the study participants (Table 2). DAP and SAP measurements do not necessarily vary in parallel and, depending on the experimental conditions and the individuals' psychological condition, one can increase whereas the other remains stable[18,19].

Some study limitations must be considered. Continuous measurements of the pressure variables were not performed. However, other studies that analyzed the cardiovascular reactivity to mental stress have also used the same methodology[2,7]. Therefore, it is believed that this procedure does not impair the internal validity of the study. Another aspect to be considered refers to the type of sample studied, that is, a convenience sample. This fact suggests caution regarding the generalization of the results. Further studies must be carried out in elderly populations with controlled arterial hypertension with the objective of investigating the association between the polymorphism of angiotensin-converting enzyme (ACE) gene and the cardiovascular reactivity at the word-color Stroop test - TESTINPACS™.

Conclusions

The computerized version of the word-color Stroop test - TESTINPACS™ is a useful tool to induce cardiovascular reactivity in young women. Experimental strategies that induce the central nervous system hyper-reactivity after a mental stress session are relevant, as they increase the number of tools that can be used in the human healthcare area that aim at the decrease of emotional stress and the prevention or treatment of arterial hypertension in its early phases. The computerized version of the Stroop test - TESTINPACS™ is available without cost to all laboratories or institutions that wish to use it.

Potential Conflict of Interest

No potential conflict of interest relevant to this article was reported.

Sources of Funding

There were no external funding sources for this study.

Study Association

This study is not associated with any post-graduation program.

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