Creative Education, 2023, 14, 1258-1268
https://www.scirp.org/journal/ce
ISSN Online: 2151-4771
ISSN Print: 2151-4755

Analyzing Response Time for Assessing the Adaptation Stress in First-Year Healthy Medical Students

Ketevan Janashia*, Ana Chikviladze, Aleksandre Ramishvili, Nikoloz Tvildiani

Central Scientific Research Laboratory, Aieti Medical School, David Tvildiani Medical University, Tbilisi, Georgia
Email: *k.janashia@dtmu.edu.ge

How to cite this paper: Janashia, K., Chikviladze, A., Ramishvili, A., & Tvildiani, N. (2023). Analyzing Response Time for Assessing the Adaptation Stress in First-Year Healthy Medical Students. *Creative Education, 14,* 1258-1268.
https://doi.org/10.4236/ce.2023.146080

Received: May 16, 2023
Accepted: June 24, 2023
Published: June 27, 2023

Abstract

We tested a hypothesis on whether first-year medical students have shown worse performance due to the new environment and stressful study regimes of medical universities than second-year students. Using simple and complex sensorimotor reaction times (SSMRT, CSMRT) measurements, in the virtual model, healthy male students of both courses were exposed to two randomized order increased visual complexity tasks, as acute stress factors. The means and standard deviations (SD) during SSMRT and CSMRT for both courses were calculated, then we calculated the Pearson correlation coefficient and coefficient of variation: $CV = \frac{SD}{Mean}$. There were no statistically significant differences between the means, no linear relation between the means and SD and no significant differences between the different CVs. This means well adaptation and less stress experienced by first-year students to the new environment in the stress recognition virtual model, this is explained by no individual differences between students of both courses, their almost equal high mental abilities, and the mobile nervous system of healthy males. It seems the new environment does not negatively affect first-year male students' performance ability. Our results contribute to a better understanding of education process-related stress and help the discovery of the factors that affect healthy male students' processing speed.

Keywords

Acute Environmental Stress, Mental Chronometry, Sensorimotor Reaction Time Tasks

1. Introduction

In several studies, the authors note that some aspects of hard and stressful teaching can have unintended negative effects on the mental and emotional health of medical students. Due to the new environment and stressful study regimes, first-year medical students have shown worse performance than second-year students. On a personal level, this stress can diminish one's capabilities and the importance of a future profession (Dyrbye, Thomas, & Shanafelt, 2005; Guthrie, et al., 1997; Moffat, McConnachie, Ross, & Morrison, 2004; Aktekin et al., 2001). Studies found that the most important stressors related to academic performance and the learning environment (Nowreen & Ahad, 2019; Damiano et al., 2021; Nebhinani, Kuppili, & Mamta, 2021).

The prevention of stress-related problems during the education process, revealing possible stress factors, and overcoming stress, especially in freshmen are very important goals of the educational process. Fast reactions, instant decision-making skills, and problem-solving are necessary for the medical profession. Humans' fast reactions are related to the time course of mental processes in the brain. The study of temporal ratios of activity of mental chronometry is important in several aspects. It shows a person's mental abilities based on subjective observations, to objectively perceive the environment in response.

Reaction time (RT) is measured by the time between a stimulus appearing and an individual's response which are relatively simple sensory-motor tasks typically administered in a laboratory setting as elementary cognitive tasks (Milner, 1986). In a complex RT task, the following processes are occurring: the sensory organs received the sensory features of the stimuli and transmitted them to the brain; the signal is identified and processed, then, the decision is made; and at the end, a corresponding motor response is carried out (Riemann & Lephart, 2002).

Studies have been conducted where RT parameters are used to better perform mental activities, make decisions, and optimally plan daily life, which is essential for managerial, sports, and other activities that require great attention and instant decision-making skills (Draper, McMorris, & Parker, 2010; Audiffren, Tomporowski, & Zagrodnik, 2008; Sanders, 1998).

It has been found that the speed of information processing increases exponentially from early childhood to early adulthood (Kail, 1991). This is followed by a long period of stability, where the speed of information processing is approximately equal and then decreases from middle age to old age (Salthouse, 2000). Cognitive retardation is considered to be a good indicator of extensive changes in brain function and intelligence, and it has been experimentally proven that it is closely related to changes in working memory and thinking (Demetriou, Mouyi, & Spanoudis, 2010). RT examination is often used to index cognitive abilities (https://www.predictiveindex.com/assessments/cognitive-assessment/) and it is an indirect characteristic of neuronal efficiency (Feldman, 2004).

Noteworthy are studies that establish the connection between RT and the individual-psychological characteristics of a person. A neurotic person performs RT determination tasks more slowly. The authors explain that this is due to the existence of a higher excitation barrier in neurotic individuals in response to stimuli of different intensities, which they suggest is explained by their relatively "weak" nervous system (Gupta & Nicholson, 1985). In an extensive study of 242 college undergraduates, neuroticism was found to be correlated with response variability, and higher neuroticism was associated with more deviations from the RT standard (Tamir & Robinson, 2005).

By Crow (Crow, 2019), neuroticism was significantly associated with faster error RT and a higher frequency of multiple responses.

According to Hick's law (Hick, 1952), in the decision-making process, an individual's RT increases by a constant amount as a function of available choices, or the "uncertainty" involved in which reaction stimulus would appear next. The RT is found to be a function of the binary logarithm of the number of available choices.

By Luce (Luce, 1986), the observed RT consists of the response preparation and motor realization components, which together compose non-decision time Ter. By the model, non-decision time Ter just shifts the distribution of DT, the RT is considered as the accumulation time, plus a constant value for non-decision processes Ter. In the more recent study by Sigman and Dehaene (Sigman & Dehaene, 2005), the non-decision component does vary across trials, however, this variability does not depend on the mean of RT, since the motor response can be carried out in parallel. Lee and Chabris (Lee & Chabris, 2013) investigated the ability of more intelligent people to respond faster to two simultaneous stimuli and concluded that the superior ability of intelligent people resided in the central processing time of the brain, not in the parallel peripheral stages such as faster stimulus perception or response of the muscles.

Current studies have found that higher scores on the Intellect aspect significantly correlate with faster and less variable response times and this advantage lies solely in the decisional, but not perceptual, stage of information processing (Willoughby, Kim, Lee, & De Young, 2023).

Given a view of cognitive ability as a component of personality, DeYoung (DeYoung, 2020) is arguing, higher levels of Extraversion were associated with faster responses, though the authors note perhaps, this fact is related to the specific task demands, instead of underlying cognitive differences, as Extraversion seems does not appear to correlate with intelligence.

Interestingly, during the tests subjects are fast adapted to the periodically generated stimuli, often the participants predict the stimuli rather than react to them (Zana & Zelei, 2020). Inattention, an emotional mood, fatigue, noise, sharp light, etc. may prolong reaction times and/or alter its distribution (Sanders, 1998).

The correlations between RT standard deviations (RTSD) and general intelligence are more pronounced than between the RT means (RTM), and perfect linear relations appear between individual differences in the RTM and RTSD.

By the diffusion model by the increasing task difficulty, RTM and RTSD increase at the same rate (Wagenmakers & Brown, 2007). However, in identical decision environments, different people demonstrate different SD. Individuals with high mental ability have smaller variable responses or smaller SD. The SD rate indicates the degree of balancing of neural processes; the smaller the SD, the more balanced the nervous system (Jensen, 2006; van Ravenzwaaij, Donkin, & Vandekerckhove, 2011).

The SD increases linearly with the mean, and the linear relation between RTM and RTSD also is found in the data outside the field of intelligence involving memory, perception, categorization, and problem-solving (Wagenmakers & Brown, 2007).

Based on these the objective of our current study was to compare SSMRT and CSMRT measurements in first and second-year male medical students in an acute stress recognition virtual model and test a hypothesis whether first-year students due to the new stressful environment are showing worse performance compared to second-year students or not.

2. Materials and Methods

An experimental study was conducted on 18 - 20 years old first and second-year healthy male medical students, in compliance with the standards adopted by the International (the Helsinki Declaration as well as data protection stipulations) and university Ethics Commission (Protocol No. # 5/2019). Written consent was obtained from all participants of the study. A brief history was filled in for each participant, indicating basic physical parameters and objective test data.

Experiments were carried out using a block and between-subject design. The research subjects were divided into 2 blocks, i.e., groups: group 1 (n = 14) included first and group 2 (n = 13) second-year students respectively. The test subjects were placed in the room one time to avoid the experience of the previous experiment. Testing was conducted after lectures, in the afternoon, all students experienced some fatigue.

The study included physically healthy, right-handed subjects without wearing glasses, visual impairment, head trauma, self-reported muscular or neurological diseases, and who did not take alcohol, coffee, or any medication for the previous 2 days, which could be affected their ability to perform the RT tests.

The computer software for a virtual model of acute stress recognition was designed and programmed by CSRL staff based on the "Python language" and the language of valid cognitive tests (http://pebl.sourceforge.net/). It operates in a specially created light and sound-shielded experimental room and is applied to stimulus-reaction pairs.

In total 25 min. lab experiments with 5 subsequent stages, including a 5-minute baseline period, and two 5-minute increasing complexity tasks (a stress condition) each preceded by a 5-minute relaxation period and finished by a 5-minute recovery period, are presented for the measurement of the simple and complex RT. The simple test includes 165 visual stimuli, complex test-164 visual stimuli. Discrimination RT involves comparing presented visual stimuli (with different configurations of interest) and then pressing the hand finger as quickly as possible on the mouse one of two buttons (left/right) according to which they appear by the display. RT tests are sorted based on the complexity of the tasks.

SSMRT tests:

Stimulus: landolt's broken rings with 3 or 5 gaps with different cuts positions (https://www.stereooptical.com/wp-content/uploads/2018/07/OPTEC-PLUS-Summary-of-Tests-v5-03-2018.pdf);

Reaction: pushing the left button.

CSMRT tests:

Stimulus: landolt's broken rings with 3 - 5 or 4 gaps with different cuts positions appeared in randomized order;

Reaction: pushing the left button if appears an odd number of rings and the right button in the case of even numbers.

Figure 1 shows landolt's broken rings with 3 and 4 gaps.

For a detailed description of the model and tests, see in our previous article (Janashia, Chikviladze, Ramishvili, & Mikeladze, 2022).

The program calculates each motion mistake and RT time associated with performing simple and complex tasks; the total number of answers, number of correct answers, and number of correct answers in percentage taking into account the speed-accuracy of each task. All these parameters appear on another computer's monitor, outside of the experimental room. Based on these parameters, the RT histogram is constructed with the RT distribution.

Since the lower limit of human physiologically possible perception in a given simple reaction time task is 100 ms, the results less than 100 ms were excluded from the study as physiologically impossible, this means that the test subject was attempting to anticipate the stimulus. In some cases, the difference between CSMRT and SSMRT became even negative, which is logically impossible and which means that the participant predicted stimuli rather than reacting to them (Jensen, 2006).

For statistical analysis of data obtained, SPSS statistical software was used based on Student's t-test; in addition, the maximum and minimum value, the mean value, and the standard deviation are summarized for each type of test. The Pearson correlation coefficient r (1-tailed) was used to measure the correlation between RTM and RTSD, and to control for baseline differences in processing speed we used the coefficient of variation $CV = \frac{RTSD}{RTM}$ (Puth, Neuhäuser, & Ruxton, 2014). The significant level was taken as 0.05.

Figure 1. Landolt's broken rings with 3 and 4 gaps.

3. Results

As we described above, we tested the null hypothesis that first-year students' due to the new environment are showing worse performance compared to second-year students. To check whether our hypothesis is true, we computed the above-mentioned parameters for use as features in the decision-making process during simple and complex sensorimotor tasks in the virtual model comparing the processing speed and efficiency of each task.

In Table 1, the absolute minimum, maximum, means (in seconds), standard deviations of SSMRT and CSMRT (in seconds) in the two groups (N), Pearson correlation coefficient r, coefficient of variations (CV) and *p*-values are shown:

As shown in Table 1, when comparing groups 1 and 2, the RT is larger in the CSMRT1 measurements compared to the CSMRT2. This can be explained by the more longer decision-making process by the brain required for the appropriate reaction in first-year medical students, however, this is not statistically significant (p = 0.064). There are no statistically significant differences between the mean values of different RT in both courses.

There are also no statistically significant differences between the SD values in both courses, which indicates no differences between the values of SD measured in different persons. At the same time, SD rates are small for each group, which indicates almost equal and high mental abilities of students involved in the study.

As a statistical check, we calculated the Pearson correlation coefficient representing the strength of linear association between Means and SDs for groups and the coefficient of variations. Comparison of linearity of the relationship between the Mean and SD of groups revealed no linear association between the variables (r = −0.116); Calculation of CV revealed a small level of dispersion around the mean, this indicates a cognitively same mode of processing speed in first- and second-year healthy male students.

Table 1. The absolute min, max, means, SDs, Pearson correlation coefficient and coefficient of variations of the different tests.

N	RT type	Mean	SD	Min	Max	CV
14	SSMRT1	0.3565	0.1445	0.17847	0.65887	0.388889
13	SSMRT2	0.2752	0.1233	0.145	0.59379	0.428571
t		1.568				
p		0.130				
14	CSMRT1	0.6683	0.1404	0.47447	0.88095	0.208955
13	CSMRT2	0.5759	0.1022	0.45222	0.71778	0.172414
t		1.942				
p		0.064				
r		−0.116				
p		0.442				

These findings mean: a new environment such as acute stress in the virtual model does not negatively affect healthy male students' performance ability.

4. Discussion

When the response time parameters for a complex reaction time test for first-year students are almost equal compared to the second-year students this means well adaptation and less stress experienced by first-year students to the new environment. Performance related to accuracy and speed of cognitive response, such as decision-making process and problem-solving can be impaired by stress, leading to decreased productivity and a tendency to make mistakes during performances.

In our case, there was no problem adapting to a new environment, which indicates the degree of stability of the males' concentration. It is in turn due to the strength and balance of neural processes, or we can say that first-year healthy male medical students did not experience some alertness or difficulty to the acute visual stress, doing well in problem-solving and therefore, they have mobile nervous system.

As seen from the results of our study, the problem of less adapting to a new environment is more related to personal problems and individual differences in persons. However, the students when they started studying at medical universities, had almost equal high mental abilities. In RT tasks they have smaller variable responses or smaller SD, the smaller the SD, the more balanced the nervous system (Jensen, 2006; van Ravenzwaaij, Donkin, & Vandekerckhove, 2011; Willoughby, Kim, Lee, & De Young, 2023).

Our results are shown that the male group of first-year medical students did not experience specific stress related to the difficulty adapting to the new environment, which coincides with the results of our previous study (Janashia, Chikviladze, Ramishvili, & Mikeladze, 2022) and with the results of a recent study (Ragab et al., 2021) that revealed female medical students were more stressed due to academics than males.

By the results of our study, we argue, that there are no personal problems, and there is no stress in first-year male medical students compared to second-year students. Seems first-year stress is more associated with stressful learning and not with any personal problems as revealed in previous publications cited in the section introduction (Guthrie, et al., 1997; Moffat, McConnachie, Ross, & Morrison, 2004; Nowreen & Ahad, 2019; Damiano et al., 2021; Nebhinani, Kuppili, & Mamta, 2021).

Our results show that male students have a good ability to concentrate on attention as argued recent article by (Rajprabha, Sharma, Kacker, & Tomar, 2019), which established that effective teaching is achieved through the concentration of the student's attention and the response time measurement is an important tool for measuring students' individual attention, concentration, arousal level, and brain process speed.

Our results show that the increased complexity of RT tasks demands more working memory, which might slow down information processing speed as shown in previous articles by (Vernon & Jensen, 1984; Vernon, Nador, & Kantor, 1985) and these are related to the significant differences between the groups in RT and intraindividual standard deviations.

As seen from the results of our study the RT really determines the alertness of a person and can be considered as an indirect index of the processing capability of the central nervous system results as established in previous study by (Bamne, Fadia, & Jadhav, 2011).

5. Conclusion

The results of our study are summarized here.

1) The response time for a complex reaction time test for first-year students is almost equal to that of second-year students.

2) There is no problem of difficulty adapting or some stress to a new environment in first-year male students compared to second-year students.

3) There are no individual differences and no personal problems in first- and second-year male medical students and both showed high mental abilities.

Our virtual model of measuring response time in simple and complex sensorimotor tasks can be suited to explore the adaptation possibilities of a person.

Our results contribute to a better understanding of education process-related stress and help the discovery of the factors that affect healthy male students' processing speed.

In order to arrive at more definite conclusions, we propose to continue such studies by collecting and analysing more data, taking into account the data of involved students' academic achievement.

Conflicts of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data Availability Statement

The detailed datasets used for analysis during the current study are available by the reasoned request.

References

Aktekin, M., Karaman, T., Senol, Y., Erdem, S., Erengin, H., & Akaydin, M. (2001). Anxiety, Depression and Stressful Life Events among Medical Students: A Prospective Study in Antalya, Turkey. *Medical Education, 35,* 12-17.

Audiffren, M., Tomporowski, P. D., & Zagrodnik, J. (2008). Acute Aerobic Exercise and Information Processing: Energizing Motor Processes during a Choice Reaction Time Task. *Acta Psychologica, 129,* 410-419. https://doi.org/10.1016/j.actpsy.2008.09.006

Bamne, S., Fadia, A., & Jadhav, A. (2011). Effect of Colour and Gender on Human Reaction Time. *The Indian Journal of Physiology and Pharmacology, 55,* 388-389.

Crow, A. J. D. (2019). Associations between Neuroticism and Executive Function Outcomes: Response Inhibition and Sustained Attention on a Continuous Performance Test. *Perceptual and Motor Skills, 126,* 623-638. https://doi.org/10.1177/0031512519848221

Damiano, R. F., de Oliveira, I. N., da S. Ezequiel, O., Lucchetti, A. L., & Lucchetti, G. (2021). The Root of the Problem: Identifying Major Sources of Stress in Brazilian Medical Students and Developing the Medical Student Stress Factor Scale. *Brazilian Journal of Psychiatry, 43,* 35-42. https://doi.org/10.1590/1516-4446-2019-0824

Demetriou, A., Mouyi, A., & Spanoudis, G. (2010). The Development of Mental Processing. In R. M. Lerner, M. E. Lamb, & A.M. Freund (Eds.), *The Handbook of Life-Span Development* (pp. 36-55). Wiley. https://doi.org/10.1002/9780470880166.hlsd001010

DeYoung, C. G. (2020). Intelligence and Personality. In R. Sternberg (Ed.), *The Cambridge Handbook of Intelligence* (pp. 1011-1047). Cambridge University Press. https://doi.org/10.1017/9781108770422.043

Draper, S., McMorris, T., & Parker, J. K. (2010). Effect of Acute Exercise of Differing Intensities on Simple and Choice Reaction and Movement Times. *Psychology Sport Exercise, 11,* 536-541. https://doi.org/10.1016/j.psychsport.2010.05.003

Dyrbye, L. N., Thomas, M. R., & Shanafelt, T. D. (2005). Medical Student Distress: Causes, Consequences, and Proposed Solutions. *Mayo Clinic Proceedings, 80,* 1613-1622. https://doi.org/10.4065/80.12.1613

Feldman, D. H. (2004). Piaget's Stages: The Unfinished Symphony of Cognitive Development. *New Ideas in Psychology, 22,* 175-231. https://doi.org/10.1016/j.newideapsych.2004.11.005

Gupta, S., & Nicholson, J. (1985). Simple Visual Reaction Time, Personality and Strength of the Nervous System: A Signal-Detection Theory Approach. *Personality and Individual Differences, 6,* 461-469. https://doi.org/10.1016/0191-8869(85)90139-4

Guthrie, E. A., Black, D., Shaw, C. M., Hamilton, J., Creed, F. H., & Tomenson, B. (1997). Psychological Stress in Medical Students: A Comparison of Two Very Different University Courses. *Stress Medicine, 13,* 179-184. https://doi.org/10.1002/(SICI)1099-1700(199707)13:3<179::AID-SMI740>3.0.CO;2-E

Hick, W. E. (1952). On the Rate of Gain of Information. *Quarterly Journal of Experimental Psychology, 4,* 11-26. https://doi.org/10.1080/17470215208416600

Janashia, K., Chikviladze, A., Ramishvili, A., & Mikeladze, L. (2022). A Study of Mental Activity among Healthy Medical Students Using a Virtual Model to Investigate Acute Cognitive Stress Effects. *European Journal of Education Studies, 9,* 305-317. https://doi.org/10.46827/ejes.v9i8.4438

Jensen, A. R. (2006). *Clocking the Mind: Mental Chronometry and Individual Differences.* Elsevier.

Kail, R. (1991). Developmental Change in Speed of Processing during Childhood and Adolescence. *Psychological Bulletin, 109,* 490-501. https://doi.org/10.1037/0033-2909.109.3.490

Lee, J. J., & Chabris, C. F. (2013). General Cognitive Ability and the Psychological Refractory Period: Individual Differences in the Mind's Bottleneck. *Psychological Science, 24,* 1226-1233. https://doi.org/10.1177/0956797612471540

Luce, R. D. (1986). Response Times Distribution in Memory Search. A Caution. In F. Klix, & H. Hagendorf (Eds.), *Human Memory and Cognitive Capabilities: Mechanisms* *and Performances* (pp. 109-121). Elsevier Science Publishers B.V.

Milner, A. (1986). Chronometric Analysis in Neuropsychology. *Neuropsychologia, 24,* 115-128. https://doi.org/10.1016/0028-3932(86)90045-X

Moffat, K. J., McConnachie, A., Ross, S., & Morrison, J. M. (2004). First-Year Medical Student Stress and Coping in a Problem-Based Learning Medical Curriculum. *Medical Education, 38,* 482-491. https://doi.org/10.1046/j.1365-2929.2004.01814.x

Nebhinani, N., Kuppili, P. P., & Mamta. (2021). Stress, Burnout, and Coping among First-Year Medical Undergraduates. *Journal of Neurosciences in Rural Practice, 12,* 483-489. https://doi.org/10.1055/s-0041-1727576

Nowreen, N., & Ahad, F. (2019). Sources of Stress among First-Year Medical Students. *International Journal of Medical Science and Public Health, 8,* 440-442. https://doi.org/10.5455/ijmsph.2019.0409215042019

Puth, M.-T., Neuhäuser, M., & Ruxton, G. D. (2014). Effective Use of Pearson's Product-Moment Correlation Coefficient. *Animal Behaviour, 93,* 183-189. https://doi.org/10.1016/j.anbehav.2014.05.003

Ragab, E. A., Dafallah, M. A., Salih, M. H. et al. (2021). Stress and Its Correlates among Medical Students in Six Medical Colleges: An Attempt to Understand the Current Situation. *Middle East Current Psychiatry, 28,* Article No. 75. https://doi.org/10.1186/s43045-021-00158-w

Rajprabha, Sharma, M., Kacker, S., & Tomar, A. (2019). Reaction Time and Academic Performance: An Association to Determine the Cognitive Status of First-Year Medical Students. *International Journal of Medical Research Professionals, 5,* 56-60.

Riemann, B., & Lephart, S. (2002). The Sensorimotor System, Part I: The Physiologic Basis of Functional Joint. *Stability Journal of Athletic Training, 37,* 71-79. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC164311

Salthouse, T. A. (2000). Aging and Measures of Processing Speed. *Biological Psychology, 54,* 35-54. https://doi.org/10.1016/S0301-0511(00)00052-1

Sanders, A. F. (1998). *Elements of Human Performance: Reaction Processes and Attention in Human Skill.* Psychology Press.

Sigman, M., & Dehaene, S. (2005). Parsing a Cognitive Task: A Characterization of the Mind's Bottleneck. *PLOS Biology, 3,* 334-349. https://doi.org/10.1371/journal.pbio.0030037

Tamir, M., & Robinson, M. D. (2005). Neuroticism as Mental Noise: A Relation between Neuroticism and Reaction Time Standard Deviations. *Journal of Personality and Social Psychology, 89,* 107-114. https://doi.org/10.1037/0022-3514.89.1.107

van Ravenzwaaij, D., Donkin, C., & Vandekerckhove, J. (2011). An Integrated Perspective on the Relation between Response Speed and Intelligence. *Cognition, 119,* 381-393. https://doi.org/10.1016/j.cognition.2011.02.002

Vernon, P., & Jensen, A. (1984). Individual and Group Differences in Intelligence and Speed of Information Processing. *Personality and Individual Differences, 5,* 411-423. https://doi.org/10.1016/0191-8869(84)90006-0

Vernon, P., Nador, S., & Kantor, L. (1985). Group Differences in Intelligence and Speed of Information-Processing. *Intelligence, 9,* 137-148. https://doi.org/10.1016/0160-2896(85)90013-3

Wagenmakers, E.-J., & Brown, S. (2007). On the Linear Relation between the Mean and the Standard Deviation of a Response Time Distribution. *Psychological Review, 114,* 830-841. https://doi.org/10.1037/0033-295X.114.3.830

Willoughby, E. A., Kim, Y., Lee, J. J., & DeYoung, C. G. (2023). The Construct Validity of

Intellect and Openness as Distinct Aspects of Personality through Differential Associations with Reaction Time. *Journal of Intelligence, 11,* Article No. 30.
https://doi.org/10.3390/jintelligence11020030

Zana, R. R., & Zelei, A. (2020). Introduction of a Complex Reaction Time Tester Instrument. *Periodica Polytechnica Mechanical Engineering, 64,* 20-30.
https://doi.org/10.3311/PPme.13807