Journal of
Research in Psychopathology
https://doi.org/10.22098/jrp.2024.12904.1173

2024; Vol. 5, No. 18
Pages: 36 - 42

Original Article

The Effectiveness of Computer-Based Cognitive Rehabilitation on Cognitive Flexibility and Selective Attention of High School Students

Vahid Mirzaei [1], Seyed Mosa Tabatabaee [2*] & Shahrokh Makvand Hosseini [3]

1. M.Sc. Student of Cognitive Psychology, Faculty of Psychology and Educational Sciences, Semnan University, Semnan, Iran.
2. Assistant Professor, Department of Cognitive Psychology, Faculty of Psychology and Educational Sciences, Semnan University, Semnan, Iran.
3. Associate Professor, Department of Psychology, Faculty of Psychology and Educational Sciences, Semnan University, Semnan, Iran.

Abstract

The current paper aimed to investigate the effectiveness of computer-based cognitive rehabilitation on cognitive flexibility and selective attention of high school students. A total of 30 high school students from Tehran were selected. The participants were randomly divided into two groups: experimental and control, using a convenience sampling method. The sample size for each group was determined to be 15, based on an effect size of 0.3, a power of 0.8, and an alpha of 0.05. The experimental group received 16 sessions of 45-minute computer-based cognitive rehabilitation intervention. The control group received no intervention. Research tools included the Wisconsin Card Sorting Test (WCST) and Stroop Color Word Test (SCWT). The data were analyzed using multivariate analysis of variance (MANOVA) with SPSS 26 software. The results showed that there was a significant difference between the experimental and control groups in some components of cognitive flexibility and selective attention. The findings demonstrated that computer-based cognitive rehabilitation intervention was effective on cognitive flexibility and selective attention of high school students.

Keywords

Computer-Based Cognitive Rehabilitation, Cognitive Flexibility Selective Attention Executive Functions

Received: 2023/05/13
Accepted: 2024/09/03
Available Online: 2024/12/01

Introduction

Three core executive functions include inhibition [inhibitory control, including self-control (behavioral inhibition) and interference control (selective attention and cognitive inhibition)], working memory (WM), and cognitive flexibility (also called set shifting, mental flexibility, or mental set shifting and closely linked to creativity). Higher-order executive functions, such as reasoning, problem solving, and planning, are built upon these core functions (Collins & Koechlin 2012, Lunt et al. 2012). Working memory involves retaining information in mind and working mentally with that information (Baddeley & Hitch, 1994; Kent, 2016; Diamond, 2020). In particular, the main cognitive mechanisms that involve an individual's executive functions include planning, problem solving, verbal reasoning, task change, initiation, cognitive flexibility, control, action monitoring, attention, and working memory (Wiest et al., 2020). Studies have shown that deficiencies in executive functions can persist at older ages and make it more difficult for students to complete homework and social work. Therefore, early diagnosis and intervention is essential to solve the problems of these students (Sonuga-Barke et al., 2002; Valera & Seidman, 2006; Mccloskey et al., 2008)

Cognitive flexibility is a vital component of executive function that facilitates self-regulation and critical thinking (Zhang et al., 2018). Cognitive flexibility is the ability to modify thinking and behavior in response to changing environmental conditions (Leber et al., 2008). Cognitive flexibility has been described as the capacity to shift attention and thinking among different tasks or functions, especially in response to needs and changes in rules (Miyake et al., 2000). It also is described as the ability to transition one's mind from old to new situations, to overcome common responses or thoughts, as well as to adapt to new situations (Moore & Malinowski, 2009; Deák, 2003). When sorting cards according to special rules, those are considered cognitively flexible if the person can sort the cards simultaneously based on the color of objects and the type of objects on the card. In general, cognitive flexibility is defined as the ability to be

Corresponding author: Assistant Professor, Department of Cognitive Psychology, Faculty of Psychology and Educational Sciences, Semnan University, Semnan, Iran. E-mail: s.mosatabatabaee@semnan.ac.ir

aware of and use all possible options simultaneously in specific situations (Martin & Rubin, 1995). Cognitive flexibility is also part of the multiple classifications originally described by Jean Piaget. In multiple task classification, participants (primarily children in whom the skill has been developed or are developing the skill) should classify objects in different ways and think about them flexibly at the same time (Cartwright, 2002) and it is also associated with other cognitive abilities such as fluid intelligence, reading ability and comprehension (Colzato et al., 2006). In general, researchers in this field generally focus on the development of cognitive flexibility between the ages of three and five (Zelazo & Frye, 1998).

Attention is one of the most important functions of the mind and a core component of the cognitive structure that plays an important role in intelligence, memory and perception. Attention deficit is one of the main causes of learning disabilities, especially mathematical disabilities (Valera & Seidman, 2006). Selective attention refers to the processes that enables an individual to focus on particular input for further processing while simultaneously suppressing irrelevant or distracting information (Lamers et al., 2010). In clinical evaluations of cognitive neuroscience, this test is considered reliable and useful (Lezak et al., 2004). However, cognitive flexibility and selective attention are broad concepts that can be studied at all ages and in different situations; Thus, according to research, there is a developmental progression from childhood to adulthood, with tasks ranging from simple to more complex. Cognitive rehabilitation refers to a wide range of evidence-based interventions (Cicerone et al., 2019; Cicerone et al., 2011). Kesler and Lacayo (2011) demonstrated that the computer-based cognitive rehabilitation program significantly increased processing speed, cognitive flexibility, verbal cognitive memory scores and vision, and also played a significant role in increasing the activity of the prefrontal cortex. Cognitive rehabilitation is a way to improve health-related features to restore lost cognitive capacity by providing targeted stimuli and specific exercises (Montoya-Murillo et al., 2020). This method includes a set of programs designed to train the brain with the aim of promoting mental and neurological functions (Maggio, 2019).

Computer-based cognitive rehabilitation is the result of integrating the findings of cognitive neuroscience and information technology based on the principle of brain flexibility. Its ultimate goal is to enhance individual functioning by improving perception, attention, memory, problem solving, alertness, flexibility and conceptualization (Cicerone et al., 2019). Among the types of cognitive rehabilitation, computer-based cognitive rehabilitation is more cost-effective than traditional face-to-face methods (Kurz, 2019).

Accordingly, the necessity of using intervention programs to improve students' flexibility, selective attention and academic achievement is evident. Hence, computer-based cognitive rehabilitation can play a significant role in improving students' cognitive flexibility and selective attention. Therefore, the main objective of the study was to examine the effectiveness of computer-based cognitive rehabilitation on cognitive flexibility and selective attention. While we expected the experimental group to have different capacities in terms of flexibility and selective attention after exposure compared to the control group, we predicted that the gap between the two groups would be reduced to such an extent that the difference could be easily ignored.

Method

Participants

This quasi-experimental, applied research used a pretest/posttest design with a control group. The statistical population included all male high school students in the 10th and 11th grades from the 17th district of Tehran who were studying during the 2020-2021 academic year. A sample of 30 students meeting the inclusion criteria was selected for the study. The subjects were randomly assigned to either the experimental or control group, with 15 students in each group. To prevent information exchange between the groups, the experimental group was chosen from one school and the control group from another school with similar cultural, social, and educational levels, ensuring no relationship between the two groups.I nclusion criteria include: aged 15 to 17, not receiving psychological and rehabilitation interventions simultaneously with the implementation of the present study, consent and cooperation of students and their parents. The research exclusion criteria include: withdrawal from the study, unpreparedness and full consent to participate in Intervention sessions and absenteeism was more than 2 sessions.

Procedure

Participants in the experimental and control groups were pre-tested during the first session and both groups were evaluated individually by The Wisconsin Card Sorting Test (WCST) and The Stroop Color and Word Test (SCWT). Then, the experimental group received 16 sessions for 8 consecutive weeks, 2 sessions per week, and each session lasted 45 minutes of computer-based cognitive rehabilitation, and the control group did not receive any intervention. At the end of the sessions, participants were evaluated using Wisconsin Card Sorting Test (WCST) and Stroop Color Word Test (SCWT).

The Wisconsin Card Sorting Test (WCST) was first developed by Grant Berg in 1948 to evaluate abstract reasoning, concept formation and strategies for responding to changing conditions (Nyhus & Barceló, 2009). It is one of the most well-known neuropsychological tests that measures cognitive flexibility, problem solving, abstract reasoning, and sustained attention. Initially, the test was designed to assess normal reasoning and abstract thinking in adults, but researchers later found it useful for studying cognitive impairments. WCST shows sensitivity to neurological conditions such as chronic alcohol consumption, frontal cortex lesions and psychiatric disorders (Lezak, 2012). The reliability estimates for the number of correct sorts, categories, and perseverative errors fall into the desirable range (rel ≥ .90) (Kopp et al., 2021).

In the WCST, the target cards are sorted according to three categories: color, number, and shape (Wang et al., 2001). In the current paper, we used a 64-card computer version of the WCST to assess cognitive flexibility. By pressing one of the four keys (B, N, M and V) on the computer keyboard, individuals must match the answer cards to the four stimulus cards at the top of the screen fixed according to the three categories: color, number, and shape. Individuals must determine the correct sorting principle and change that principle when the test changes (Zhang et al., 2018). The Stroop Color and Word Test (SCWT) was developed by John Ridley Stroop in 1935 to assess selective attention and cognitive flexibility as well as the ability to shift cognitive sets (Spreen & Strauss, 1998). The SCWT provides a measure to assess of mental flexibility and the ability to inhibit the dominant response (Wecker et al., 2000). In order to check the reliability of Wisconsin cards, the internal consistency (Cronbach's alpha coefficient) was calculated as 74% (Shahgholian et al., 2012).

Instrument

The tools used in this research were the Wisconsin Card Sorting Test (WCST) and the Stroop Color and Word Test (SCWT). The computerized cognitive rehabilitation intervention was implemented using the Captain's Log MindPower Builder, 2020 version.

Results

Multivariate analysis of variance (MANOVA) was used to evaluate the effectiveness of computer-based cognitive rehabilitation on cognitive flexibility. The normality hypothesis was tested using Shapiro-Wilk Test. The results showed normality of all components of cognitive flexibility in the distribution of scores (P> .05). Another assumption of multivariate analysis of variance is the homogeneity of variances between the two groups. Levene's test results showed the variances of the two groups were homogenous in both the right and wrong components (P: .01); however, the variance of the two groups is not homogenous in the perseveration component. Nevertheless, since the number of participants in the experimental and control groups is equal, there is no limitation on the use of multivariate analysis of variance. Box's M test (Box's M: 28.114, $F_{(6.3680.302)}$: 4.137, Sig:.001) is significant, i.e. the matrix of covariance's of the two groups is not equal. Therefore, multiple Wilks Lambda statistic was used. Wilks Lambda statistic was effective (Wilks' Lambda: .280, $F_{(\text{Hypothesis df: 3, Error df: 26})}$: 22.327, Sig .: .001, Partial Eta Squared: .720). Computer-based cognitive rehabilitation is significant on the linear composition of cognitive flexibility components and the effect of experimental computer cognitive rehabilitation intervention on the linear composition of cognitive flexibility components is equal to ./720 which is a high level. Therefore, there is a significant difference between the experimental and control groups in at least one of the components of cognitive flexibility. Table (2) shows the results of comparing the components of cognitive flexibility.

Table 1. Mean and standard deviation of experimental and control groups in cognitive flexibility components

		Experimental Group		Control Group	
		Mean	SD	Mean	SD
Total correct responses	Pretest	40.40	6.613	40.67	3.200
	Posttest	40.20	2.757	39.73	2.815
Total responses errors	Pretest	11.07	3.654	14.80	6.281
	Posttest	5.87	3.021	18.20	4.799
Perseverative errors	Pretest	1.07	0.884	2.87	2.949
	Posttest	0.27	0.594	3.93	2.374d

Table 2. Analysis of variance to compare experimental and control groups in cognitive flexibility components

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Group	Total correct responses	1.633	1	1.633	.210	.650	.007
	Total responses errors	1140.833	1	1140.833	70.964	.000	.717
	Perseverative errors	100.833	1	100.833	33.665	.000	.546
Error	Total correct responses	217.333	28	7.762			
	Total responses errors	450.133	28	16.076			
	Perseverative errors	83.867	28	2.995			

According to Table 2, there is a significant difference between the experimental and control groups in terms of two components: incorrectness and perseveration. According to Table 1, the mean of the experimental group is lower than that of the control group in both the "incorrectness" and "perseveration" components. The effect of computer-based rehabilitation intervention on the component at perseveration is 0.546 on average and on the incorrectness component is 0.717 above average. There is no significant difference between the experimental and control groups in terms of the correct component.

Table 3. Mean and standard deviation of experimental and control groups in selective attention components

		Experimental Group		Control Group	
		Mean	SD	Mean	SD
Congruent experimental time	Pretest	47.60	6.998	48.73	7.275
	Posttest	38.33	4.952	50.60	5.329
Incongruent experimental time	Pretest	51.87	9.141	52.27	9.051
	Posttest	40.40	5.316	53.80	5.955
Congruent error number	Pretest	0.47	0.834	0.73	1.438
	Posttest	0.53	0.743	0.13	0.352
Incongruent error number	Pretest	1.13	1.457	2.13	3.314
	Posttest	0.72	0.589	2.27	2.219
Congruent RT	Pretest	994.47	142.114	1013.53	136.449
	Posttest	816.80	84.157	1045.67	100.565
Incongruent RT	Pretest	1077.53	176.045	1076.87	164.412
	Posttest	835.93	100.651	1100.47	87.169
Interference score	Pretest	1.07	2.404	1.93	2.963
	Posttest	0.13	1.125	2.60	3.043
Interference time	Pretest	83.07	63.510	63.33	63.030
	Posttest	39.40	23.829	45.87	50.756

Multivariate analysis of covariance (MANCOVA) was used to compare the experimental and control groups in the components of selective attention. The normality hypothesis was investigated using Shapiro-Wilk Test. The results showed normality of all components of selective attention in the distribution of scores (P> .05). Another multivariate analysis of variance hypothesis is the homogeneity of variances of the two groups, that Levene's test results showed the components of homogeneous test time, heterogeneous test time, homogeneous response time and heterogeneous response time, the variances of the two groups are equal. (P: .05). However, the variances were not equal for the components of the number of heterogeneous errors, interference score, and time of variance. Since the number of participants in the experimental and control groups is equal, there is no limitation on the use of multivariate analysis of covariance. Interference score pretest was used as an auxiliary variable. Regression homogeneity was also established. (Sig<0.5), Box's M test (Box's M: 158.411, $F_{(36.2638.045)}$: 3.022, Sig:.001) is significant, i.e. the matrix of covariance's of the two groups is not equal. Therefore, multiple Wilks Lambda statistic was used. Wilks Lambda statistic was effective (Wilks' Lambda: .257, $F_{(\text{Hypothesis df: 3, Error df: 26})}$: 22.327, Sig .: .001, Partial Eta Squared: .743). Therefore, the effectiveness of computer-based cognitive rehabilitation on the linear composition of selective attention components is significant and the effect size of experimental computer-based cognitive rehabilitation intervention on the linear composition of selective attention components is .720, which is high level.

Table 4. Analysis of variance to compare experimental and control groups in selective attention components

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Covariate variable	Congruent experimental time	22.195	1	22.195	.834	.369	.030
	Incongruent experimental time	20.980	1	20.980	.650	.427	.024
	Congruent error number	.057	1	.057	.163	.690	.006
	Incongruent error number	3.201	1	3.201	1.224	.278	.043
	Congruent RT	3418.913	1	3418.913	.389	.538	.014
	Incongruent RT	3440.789	1	3440.789	.380	.543	.014
	Interference score	2.260	1	2.260	.421	.522	.015
	Interference time	1303.332	1	1303.332	.824	.372	.030
Group	Congruent experimental time	1047.583	1	1047.583	39.353	.000	.593
	Incongruent experimental time	1256.672	1	1256.672	38.954	.000	.591
	Congruent error number	1.085	1	1.085	3.113	.089	.103
	Incongruent error number	15.093	1	15.093	5.772	.023	.176
	Congruent RT	370521.500	1	370521.500	42.154	.000	.610
	Incongruent RT	497066.096	1	497066.096	54.831	.000	.670
	Interference score	41.181	1	41.181	7.664	.010	.221
	Interference time	133.403	1	133.403	.084	.774	.003
Error	Congruent experimental time	718.738	27	26.620			
	Incongruent experimental time	871.020	27	32.260			
	Congruent error number	9.410	27	.349			
	Incongruent error number	70.596	27	2.615			
	Congruent RT	237320.821	27	8789.660			
	Incongruent RT	244765.878	27	9065.403			
	Interference score	145.073	27	5.373			
	Interference time	42712.002	27	1581.926			

Table (4) shows that there is a significant difference between the experimental and control groups in terms of mean components of homogeneous test time, heterogeneous test time, number of heterogeneous errors, homogeneous response time, heterogeneous response time and interference score. According to table 3, the mean of the experimental group in these components is lower than that of the control group. The effect size of the computer-based cognitive rehabilitation intervention on the homogeneous test time component was 0.593 above average, on the homogeneous test time component was 0.591 above average, on the homogeneous error number component was 0.176 on the low level, on the homogeneous response time component was 0. 610 is above average on the homogeneous response time component 0.670 is above average and on the interference score component is 0.221 on the low. Notably, there is no significant difference between the two groups in the components of the number of homogeneous errors and the time of interference.

Discussion

The current paper aimed to evaluate the effectiveness of computer-based cognitive rehabilitation on cognitive flexibility and selective attention of high school students, with the intention of determining its potential use in educational and rehabilitation interventions. The findings indicated a significant effect size for a computer-based cognitive rehabilitation program (Mansbach et al., 2017). Kotwal, Burns & Montgomery (1996) observed significant behavioral changes by reinforcing on-the-job behavior and reducing destructive behaviors at school using the Brain Train / Captain's Log computer-based cognitive rehabilitation program. Little is known about the effectiveness of computer-based cognitive rehabilitation in the school environment. Wiest, Wong, Bacon, & Rosales (2020) examined the effect of computer-based cognitive rehabilitation on 17 participants from a school for students with different learning abilities. 9 students participated in a computer-based cognitive rehabilitation program for 20 hours while the remaining 8 students did not participate in this training. Pretest and posttest differences showed that auditory working memory ability was significantly improved only for those who received the training program. These results provide initial support for the effectiveness of computer-based cognitive training in the school environment to improve working memory. Combining computer-based cognitive rehabilitation with other techniques may be beneficial for children with ADHD symptoms (Rabiner et al., 2010). Steiner et al., (2013) showed the effectiveness of two interventions in children with ADHD symptoms, a neurofeedback program and a computer-based cognitive rehabilitation program, Brain Train / Captain's Log. After an average of 23 sessions in their schools, parents had a significant improvement in symptoms associated with the disorder compared to controls. In subsequent studies, the same authors showed that the effects were maintained in the 6-month follow-up (Steiner et al., 2014). In both experimental and control groups, some components of cognitive flexibility and selective attention show a significant difference in terms of linear composition. This paper results are consistent with that of González-Palau, et al., (2013). They stressed the importance of designing new computer-based cognitive rehabilitation programs and their research results show the positive effect of a long-term memory training program for three months. This paper results are also consistent with that of Gaitán , et al., (2013). They studied the effect of the tools used in the cognitive rehabilitation program on strengthening attention, memory and problem solving and concluded that it strengthens attention, working memory and problem solving. This paper results are also consistent with the Meta-analysis performed by Peijnenborgh, Hurks, Aldenkamp, Vles & Hendriksen (2016).

Conclusion

Therefore, the findings of the current paper confirmed the effectiveness of computer-based cognitive rehabilitation on some components of cognitive flexibility and selective attention. It is suggested that the present study be conducted completely virtually to compare its effectiveness. Also, using different functional imaging technologies of the brain to evaluate the effectiveness of this type of intervention is recommended.

Limitations

The present study includes a small sample that limits its generalizations. Nevertheless, this study supports computer-based cognitive learning in the school environment. Also limited duration of computer-based cognitive rehabilitation is possibly affecting some of the current findings. Generally, the results of the current study seem promising for computer-based cognitive rehabilitation as a suitable tool to increase or improve cognitive skills among students with learning disabilities.

Disclosure Statement

No potential conflicts of interest are reported by the authors.

ORCID

Seyed Mosa Tabatabaee: https://orcid.org/0000-0002-9378-9770

References

Cartwright, K. B. (2002). Cognitive development and reading: The relation of reading-specific multiple classification skill to reading comprehension in elementary school children. *Journal of Educational Psychology*, *94*(1), 56–63. doi:10.1037/0022-0663.94.1.56

Cicerone, K. D., Goldin, Y., Ganci, K., Rosenbaum, A., Wethe, J. V., Langenbahn, D. M., … Harley, J. P.

(2019, August 1). Evidence-Based Cognitive Rehabilitation: Systematic Review of the Literature From 2009 Through 2014. *Archives of Physical Medicine and Rehabilitation*. doi:10.1016/j.apmr.2019.02.011

Cicerone, KD, Langenbahn, D., Rehabilitation, C. B.-… and, & 2011, U. (2011). Evidence-based cognitive rehabilitation: updated review of the literature from 2003 through 2008. *Elsevier*. Retrieved from https://www.sciencedirect.com/science/article/pii/S0003999310009500

Colzato, L. S., van Wouwe, N. C., Lavender, T. J., & Hommel, B. (2006). Intelligence and cognitive flexibility: fluid intelligence correlates with feature "unbinding" across perception and action. *Psychonomic Bulletin & Review*, *13*(6), 1043–1048. doi:10.3758/bf03213923

Deák, G. O. (2003). The Development of Cognitive Flexibility and Language Abilities. In *Advances in child development and behavior, Vol. 31.* (pp. 271–327). Deák, Gedeon O.: Department of Cognitive Science, University of California, San Diego, 9500 Gilman Dr., La Jolla, CA, US, 92093-0515: Academic Press.

Diamond, A. (2013). Executive functions. *Annual Review of Psychology*, *64*, 135–168. doi:10.1146/annurev-psych-113011-143750

Diamond, A. (2020). Executive functions. *Handbook of Clinical Neurology, 173*, 225–240. doi:10.1016/B978-0-444-64150-2.00020-4

González-Palau, F., Franco, M., Toribio-Guzmán, J. M., Losada, R., Parra Vidales, E., & Bamidis, P. (2013). Designing a computer-based rehabilitation solution for older adults: The importance of testing usability. *PsychNology Journal*, *11*, 119–136.

Homack, S., & Riccio, C. A. (2004). A meta-analysis of the sensitivity and specificity of the Stroop Color and Word Test with children. *Archives of Clinical Neuropsychology : The Official Journal of the National Academy of Neuropsychologists*, *19*(6), 725–743. doi:10.1016/j.acn.2003.09.003

Kent, P. (2016). Working Memory: A Selective Review. *Applied Neuropsychology: Child*, *5*, 163–172. doi:10.1080/21622965.2016.116749

Kesler, S. R., Lacayo, N. J., & Jo, B. (2011). A pilot study of an online cognitive rehabilitation program for executive function skills in children with cancer-related brain injury. *Brain Injury*, *25*(1), 101–112. doi:10.3109/02699052.2010.536194

Kopp, B., Lange, F., & Steinke, A. (2021). The Reliability of the Wisconsin Card Sorting Test in Clinical Practice. *Assessment*, *28*(1), 248–263. doi:10.1177/1073191119866257

Kotwal, D. B., Burns, W. J., & Montgomery, D. D. (1996). Computer-Assisted Cognitive Training for ADHD: A Case Study. *Behavior Modification*, *20*(1), 85–96. doi:10.1177/01454455960201004

Kurz, A. (2019). Cognitive stimulation, training, and rehabilitation. *DIALOGUES IN CLINICAL NEUROSCIENCE*, *21*(1), 35-41.

Leber, A. B., Turk-Browne, N. B., & Chun, M. M. (2008). Neural predictors of moment-to-moment fluctuations in cognitive flexibility. *PNAS Proceedings of the National Academy of Sciences of the United States of America*, Vol. 105, pp. 13592–13597. doi:10.1073/pnas.0805423105

Lezak, M., Howieson, D., Loring, D., & Fischer, J. (2004). *Neuropsychological assessment*. Retrieved from https://books.google.com/books

Maggio, M. G., De Luca, R., Molonia, F., Porcari, B., Destro, M., Casella, C., … Calabro, R. S. (2019). Cognitive rehabilitation in patients with traumatic brain injury: A narrative review on the emerging use of virtual reality. *Journal of Clinical Neuroscience : Official Journal of the Neurosurgical Society of Australasia*, *61*, 1–4. doi:10.1016/j.jocn.2018.12.020

Mansbach, W. E., Mace, R. A., & Clark, K. M. (2017). The Efficacy of a Computer-Assisted Cognitive Rehabilitation Program for Patients with Mild Cognitive Deficits: A Pilot Study. *Experimental Aging Research*, *43*(1), 94–104. doi:10.1080/0361073X.2017.1258256

Martin, M. M., & Rubin, R. B. (1995). A new measure of cognitive flexibility. *Psychological Reports*, *76*(2), 623–626. doi:10.2466/pr0.1995.76.2.623

Mccloskey, G., Perkins, L., & Diviner, B. (2008). Assessment and Intervention for Executive Function Difficulties. *Assessment and Intervention for Executive Function Difficulties*, 1–362. doi:10.4324/9780203893753

Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., Howerter, A., & Wager, T. D. (2000). The unity and diversity of executive functions and their contributions to complex "Frontal Lobe" tasks: a latent variable analysis. *Cognitive Psychology*, *41*(1), 49–100. doi:10.1006/cogp.1999.0734

Montoya-Murillo, G., Ibarretxe-Bilbao, N., Peña, J., & Ojeda, N. (2020). Effects of Cognitive Rehabilitation on Cognition, Apathy, Quality of Life, and Subjective Complaints in the Elderly: A Randomized Controlled Trial. *The American Journal of Geriatric Psychiatry : Official Journal of the American Association for Geriatric Psychiatry*, *28*(5), 518–529. doi:10.1016/j.jagp.2019.10.011

Moore, A., & Malinowski, P. (2009). Meditation, mindfulness and cognitive flexibility. *Consciousness and Cognition*, *18*(1), 176–186. doi:10.1016/j.concog.2008.12.008

Nyhus, E., & Barceló, F. (2009). The Wisconsin Card Sorting Test and the cognitive assessment of prefrontal executive functions: a critical update. *Brain and Cognition*, *71*(3), 437–451. doi:10.1016/j.bandc.2009.03.005

Rabiner, D. L., Murray, D. W., Skinner, A. T., & Malone, P. S. (2010). A randomized trial of two promising computer-based interventions for students with attention difficulties. *Journal of Abnormal Child Psychology*, *38*(1), 131–142. doi:10.1007/s10802-009-9353-x

Sonuga-Barke, E. J. S., Dalen, L., Daley, D., & Remington, B. (2002). Are planning, working memory, and inhibition associated with individual differences in preschool ADHD symptoms? *Developmental Neuropsychology*, *21*(3), 255–272. doi:10.1207/S15326942DN2103_3

Spreen, O., & Strauss, E. (1998). A compendium of neuropsychological tests: Administration, norms, and commentary, 2nd ed. In *A compendium of neuropsychological tests: Administration, norms, and commentary, 2nd ed.* New York, NY, US: Oxford University Press.

Steiner, N. J., Frenette, E. C., Rene, K. M., Brennan, R. T., & Perrin, E. C. (2014). In-school neurofeedback training for ADHD: sustained improvements from a randomized control trial. *Pediatrics*, *133*(3), 483–492. doi:10.1542/peds.2013-2059

Steiner, N. J., Sheldrick, R. C., Gotthelf, D., & Perrin, E. C. (2011). Computer-based attention training in the schools for children with attention deficit/hyperactivity disorder: a preliminary trial. *Clinical Pediatrics*, *50*(7), 615–622. doi:10.1177/0009922810397887

Strauss, esther, Sherman, E., & Spreen, O. (2006). *A Compendium of Neuropsychological Tests, Third Edition*.

Stroop, J. R. (1935). Studies of interference in serial verbal reactions. *Journal of Experimental Psychology*, *18*(6), 643–662. doi:10.1037/h0054651

Valera, E. M., & Seidman, L. J. (2006). Neurobiology of Attention-Deficit/Hyperactivity Disorder in Preschoolers. *Infants & Young Children*, *19*(2). Retrieved from https://journals.lww.com/iycjournal/Fulltext/2006/

Wang, L., Kakigi, R., & Hoshiyama, M. (2001). Neural activities during Wisconsin Card Sorting Test--MEG observation. *Brain Research. Cognitive Brain Research*, *12*(1), 19–31. doi:10.1016/s0926-6410(01)00022-2

Wecker, N. S., Kramer, J. H., Wisniewski, A., Delis, D. C., & Kaplan, E. (2000). Age effects on executive ability. *Neuropsychology*, *14*(3), 409–414. doi:10.1037//0894-4105.14.3.409

Wiest, D., Wong, E., Bacon, J., Rosales, K., & Wiest, G. (2020). The Effectiveness of Computerized Cognitive Training on Working Memory in a School Setting. *Applied Cognitive Psychology*, *34*. doi:10.1002/acp.3634

Zelazo, P. D., & Frye, D. (1998). Cognitive complexity and control: II. The development of executive function in childhood. *Current Directions in Psychological Science*, *7*(4), 121–126. doi:10.1111/1467-8721.ep10774761

Zhang, H., Zhou, H., Lencz, T., Farrer, L., Kranzler, H., & Gelernter, J. (2018). Genome-wide association study of cognitive flexibility assessed by the Wisconsin Card Sorting Test. *American Journal of Medical Genetics Part B: Neuropsychiatric Genetics*, *177*, 511–519. doi:10.1002/ajmg.b.32642