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Effectiveness of Gagne's Model of Instructional Design on Attention Level and Working Memory Capacity of Students with Attention Deficit Hyperactivity Disorder

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Abstract

This study aimed to determine the effectiveness of Gagne's model of instructional design on the attention and working memory capacity of students with attention deficit hyperactivity disorder. This study adopted a quasi-experimental design with pretest-posttest and a control group. The statistical population of the current research consisted of all fifth-grade female students with attention deficit hyperactivity disorder in Tabriz in the academic year 2021-2022. In this study, 30 students with attention problems (scores higher than 72 in the Connors Parent Questionnaire) were selected as the sample and randomly assigned to the experimental and control groups. The experimental group underwent eight training sessions, four sessions per week, each for 30 minutes, using the Gagne's training model while the control group did not receive any training. It should be mentioned that the computer version of the selective and divided attention and working memory tests were used to collect data. The data were analyzed using multivariate analysis of covariance (MANCOVA) and SPSS 22 software. The results showed that Gagne's model of instructional design is effective in increasing divided attention (P <0.048), selective attention (P <0.018), reducing reaction time (P <0.009), and increasing working memory capacity (P <0.047) in students with attention deficit hyperactivity disorder. Therefore, it is suggested that the content of courses requiring great attention and concentration be designed using Gagne's model of instructional design and presented to students in order to increase the amount of divided attention , selective attention and working memory capacity and reduce reaction time.

Keywords: Attention, Attention Deficit Hyperactivity Disorder, Gagne's model, Reaction time, Working memory capacity

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Introduction

Attention Deficit Hyperactivity Disorder (ADHD) is one of the most prevalent childhood disorders that has attracted the interest of psychologists and psychiatrists (Biederman, 2005). According to data from an adult population research, only 50% of the participants with clinical symptoms of ADHD could retrospectively

remember an onset before the age 7, contrary to 95% who could remember an onset prior to the age 12 and 99% before the age of 16 (Kieling et al., 2010). It is one of the most common childhood neurobehavioral disorders affecting a large proportion of the world's population (3 to 7%) (Faraone et al., 2003).

ADHD is a persistent pattern of inattention or hyperactivity and impulsive behaviors that are more severe and more common than those commonly seen in children with similar developmental levels (Vergauwe et al., 2021). Specific symptoms must manifest before the age of 7 or 12 to make this diagnosis. Depending on the growth rate, the disorder must exist in at least two areas, and the individual's performance must be impaired in social, educational, or occupational settings (Enger, 2018; Kieling et al., 2010). The World Child Health Organization estimates the prevalence of attention deficit hyperactivity disorder in primary school children in the range of 2 to 8 percent and the prevalence of ADHD in elementary school students in Iran ranged between 3.17% and 17.3% (Namdari et al., 2012; Safavi et al. 2016; Shooshtari et al,. 2021).

According to some studies, children with ADHD suffer from profound brain dysfunction. Lounsbury et al. (2014) explained that attention is an individual's ability to process information and that information processing capacity is limited; therefore, it is challenging for a person with ADHD to perform one or more than one tasks at once (Fillauer et al., 2020) and if the person can focus on stimuli, it is limited. Suppose one tries to pay attention to too many stimuli simultaneously. In that case, interference occurs, and the activity on one of the two tasks is reduced (Mortazavi, 2010). Therefore, the three main components of selective attention, divided attention, and reaction time in attention are important: 'Selective attention', the ability to focus on a task or a specific task for an approximate length of time is instantaneous and without distraction. Divided attention is the ability of the process to divide attention between two things at the same time and 'Reaction time' refers to the time it takes from the time a stimulus is received to the time it responds to that stimulus (Fillauer et al., 2020).

Another vital area among executive functions is Working Memory (WM). Students with ADHD have shown evidence of impairment in working memory, transfer, and adaptation of the spatial visual work memory areas (Enger, 2018). This deficiency manifests itself in the occurrence of math problems, in telling time and approximate arithmetic, as well as in reading difficulties, poor verbal short-term memory, and processing speed (Berryhill, 2008). One of the main reasons for this deficiency in memory tasks is that these children, unlike their natural counterparts, do not use effective memory strategies such as mindfulness (Taghipour Javan et al., 2013). Research has shown that children with ADHD have much poorer working memory performance than normal children (Enger, 2018). In 1974, Baddeley and Hitch introduced the multi-component working memory model. This theory consists of a model including three components: the administrative center, the phonetic loop, and the visual-spatial outline, with the administrative center functioning as a control center for information types, which directs information between the phonetic and visual-spatial components. The administrative center oversees attention to relevant information, suppresses irrelevant information and inappropriate actions, and coordinates cognitive processes when multiple tasks are performed simultaneously. The phonetic loop stores phonetic information (i.e., the sound of language) and prevents it from being transformed through continuous updating in a practice loop. The spatial visual design keeps the record of spatial and visual data (Levin, 2012).

Many tasks are proposed for evaluating working memory capacity. The n-back task is a typical paradigm for evaluating working memory capacity (Kirchner, 1958). Participants in the n-back task are shown a variety of visual stimuli. They are asked whether each stimulus matches one from n trials before. In a 2-back task, participants must determine if the present letter is the same as the letter in trial n-2. The task requires a series of cognitive functions, including the encoding and temporary storage of each stimulus in the stimulus sequence in working memory and the constant updating of incoming stimuli. Moreover, irrelevant items must be blocked, and the WM must be cleared of the currently irrelevant items. A counting and matching process is required in the working memory to determine if the upcoming and previously-stored stimuli are identical (Rac-Lubashevsky & Kessler, 2016).

One of the methods applied to reduce the ADHD rate is using appropriate educational methods and models (Frey, 2011). The pattern of educational design used by the teacher is among the factors affecting the level of attention and working memory of students. One of the most important educational models is Gagne's model of instructional design (Treviño, et al, 2021). In Gagne's model of instructional design, all educational components are divided into five categories of learning capabilities. For each of the five capabilities, the existence of two categories of internal and external conditions is essential. To realize each of the capabilities, according to the internal and external requirements, they offer educational events, which include nine stages: attracting attention, informing about educational goals, recalling past learnings,

providing educational materials, providing learning guidance, performing in tests, giving feedback on performance accuracy, providing performance appraisal, encouraging and facilitating reminiscence and transfer of knowledge (Nowruzi & Razavi, 2011).

Numerous studies have been done on the application of the Gagne's model of instructional design (Chen, 2002), in his research, concluded that students who were trained with this model paid more attention to high-level thinking retention. Davidovitch and Milgram (2016) also showed a significant positive relationship between attention and the effectiveness of Gagne's model. Thorell et al. (2009) showed working memory training can have strong influence on preschool children's spatial and verbal working memory. Moreover, Spaulding's (2017) research showed that the cognitive exercises in Gagne's model mainly emphasize the functions of attention, resistance to distraction, and conceptual flexibility.

Although, in recent years, various research and educational efforts have been made to improve selective and divided attention deficiencies of children with ADHD using specific positive strategies, there is still a need for more research in this area (Unsworth & Robison, 2020). Furthermore, no research has been done so far to determine the effectiveness of educational design model on attention and memory of students with ADHD, and since the Gagne's model of instructional design is one of the practical educational design models in the educational system of Iran, determining the effectiveness of this model on the attention and working memory capacity of students with attention disorders can help teachers in providing adequate education and students in meaningful learning. Therefore, the present study sought to investigate the effectiveness of Gagne's model of instructional design on the level of attention and working memory capacity of students with ADHD.

Method

Design

This study adopted a quasi-experimental design with pretest-posttest and a control group.

Participants

The statistical population of the present study includes all the female elementary students of grade five with attention disorder in Tabriz province during the academic year of 2021-2022. For selecting the participants, the Connors parent questionnaire was completed by the parents of female elementary school students and then 30 students with attention deficit hyperactivity disorder were purposefully selected and randomly assigned to the experimental and the control groups. Purposeful sampling was performed so that 30 students who obtained scores above 72 in the Connors parent questionnaire and whose academic record was mentioned as ADHD were identified as people with attention problems. Then 15 students were assigned to the experimental group, and 15 people were assigned to the control group randomly. The research sample size was selected using the Cohen table with power of 0.50 and Cohen's d 0.8 (Cohen, 1988).

Instruments

In the present study, the Connors parent questionnaire was completed by the parents to identify students with ADHD. The reliability of the test in the present study obtained through Cronbach's alpha was .89.

Also, in order to examine attention, the translated version of the selective and divided attention test (the translated version designed by Sina Institute with the collaboration of Monavar Yazdi) was used. This test examines selective and divided attention in different age groups in two steps: during the first step, the stage of examining selective and divided attention is performed, and two letters of the alphabet (like M and S) are represented. Then the experiment starts. If the mentioned letters were represented, the participant should click, and if other letters were represented, she/he should not click. The time gap between presenting two stimuli is half a second (The time gap and letters could be changed). Then, the second stage of the selective and divided attention test is performed. In this stage, both of the above letters are represented on the two sides of the monitor. The participants should answer just by the right hand to the right stimulus and with the left hand to the left stimulus, and in the case of change in letters, they should not answer. Answering in this state is considered an error. To measure reaction time, the time it took for each student to respond to the test was measured. In the present study, the reliability was estimated to be .82 for selective attention, .84 for scattered attention, and .79 in reaction time.

Kirchner's (1958) n-back working memory task was used to examine the students' working memory capacity. The reliability of the test obtained through Cronbach's alpha was .80.

Procedure

After selecting the participants, the experimental group was trained for six sessions using the instructional design model (Reigeluth, 1999), and the control group received no training. Inclusion criteria included: 1. Similar cultural and economic characteristics (selection

of schools from average socio-economic profiles); 2. Raven IQ test (based on academic record), and 3. Average academic performance (the grade point average was considered from 17 to 19 in the fifth grade). Exclusion criteria of the research included: 1. Unwillingness to attend training sessions; and 2. Absence from more than two sessions in the training sessions. The stages experienced by the experimental group is demonstrated in Table 1.

After designing and making the educational package in the science course, experts were asked for their opinions. The experts included five teachers with experience in science, three educational psychologists, and two curriculum specialists. The questionnaire included the opinion of experts regarding the validation of each of the training sessions, in three options: high, medium and low. To check the final validity of the educational package, the formula of the content validity ratio and the value determined in the table based on the number of participants in the test was used. According to the number of participants (10 people) and based on the values of Lawshe's table, the contents of the meetings whose content validity ratio was more than 0.62 were accepted. All the content received a content validity score higher than the value determined in the table. According to the results, the average Lawshe coefficient obtained for the entire educational package was estimated as CVR = 0.847, so the educational package was recognized as valid in terms of content. The research was conducted after obtaining the individuals' permission and written consent.

It is noteworthy that all the ethical principles proposed by the American Psychological Association were observed in this study, such as obtaining the written consent of the sample, confidentiality of the information obtained and acknowledging the participants' free will to leave the meeting at any intervention stage.

Table 1.
Instruction Manual by Gagne's Model of Instructional Design (Gagne & Brigez, 2009)

Stages	Instruction
Attracting attention	The students get familiar with the experiment by watching videos about how to perform the tasks or by hanging pictures on the classroom wall. The researcher talks about the effects and the results of scientific experiments. The teacher pays attention to the students' spelling and perceptions and corrects the probable mistakes.
Informing the learner of the educational purposes	The primary purpose is to carry out scientific experiments, and the students ought to learn how to do the experiments. The teacher informs that they should be able to indicate the way of doing the experiments at the end of the session.
Recalling the past learning	The teacher reminds their past learning and other experiments the students have learned and could do correctly; she/he wants them to indicate the way they perform the experiments when she points to them.
Presenting stimuli	By presenting keywords, the students get familiar with the experiments and after that it is turned to their practice. All the students are asked to come to the board and solve the problems.
Learners' guideline	In all the previous stages, the teacher directs the students to solve their problems; those who have problems performing the experiments should receive much instruction and use different methods if possible.
Presenting feedback in the case of correct performance	The student receives immediate feedback by comparing his/her experiment with the text book. In the left corner of the book, there are options to present feedback that the teacher offers regarding his/her performance and use descriptive sentences.
Performance evaluation	The students are asked to perform the new experiments and indicate the problems.
Improved retention and transferring	The students are asked to design and perform new experiments at home and present them.

In the present study, multivariate analysis of covariance and univariate analysis of covariance was used to test the research hypotheses.

Findings

This section presents the demographic information of the research samples.

Table 2.
Demographic Information Related To the Age of the Research Samples

Age	Experimental Group		Control Group		*p*
	n	Percent	n	Percent	
9 - 10	2	13.5	2	13.5	0.369
10 - 11	12	80	13	86.5	
11 - 12	1	6.5	0	0	
Total	15	100	15	100	

Due to the nominal variability, Chi-square test was used to evaluate the difference between the groups in terms of age. The results show that the two groups were similar in terms of age.

In the following tables, descriptive statistics related to the research variables in both the experimental and control groups and two stages of pre- and post-test are presented:

Table 3.
Descriptive Data Related to the Research

Variables	Test	Control Group		Experimental Group	
		Mean	Standard Deviation	Mean	Standard Deviation
Total Score of Attention	Pretest	107.60	7.57	106.56	6.80
	Post-test	112.26	5.27	112.26	7.10
Divided Attention	Pretest	45.56	2.52	20.54	2.67
	Post-test	55.60	5.01	54.77	2.60
Selective Attention	Pretest	41.15	5.51	58.76	5.75
	Post-test	42.60	5.75	45.76	5.50
Reaction Time	Pretest	15.70	1.26	16.26	1.76
	Post-test	15.85	1.55	15.70	1.57
Capacity of the Working Memory	Pretest	65.55	5.55	65.01	5.27
	Post-test	65.75	11.65	72.66	10.25

In this section, the assumptions of covariance analysis are examined. First, the normality of the scores related to research variables was examined. Given that the significance level of all variables of divided attention (p= 0.10), selective attention (p= 0.463), reaction time (p= 0.80), and working memory (p = 0.69) in the Shapiro-Wilk test was higher than 0.05, the distribution of the scores of variables in the studied samples is normal.

Then, the hypothesis of homogeneity of the regression slopes, one of the basic assumptions of analysis of covariance, was investigated. Considering that the significance level of all four variables in divided attention (p = 0.60), selective attention (p = 0.11), reaction time (p= 0.05), and working memory (p = 0.05) in the experimental group was higher than 0.05, it can be claimed that the assumption of homogeneity of the regression slopes for analysis of covariance is established, and there is a linear relationship between the dependent and independent variables within the groups.

Levene's test was also used to test the assumption of variances in the study groups, which is another assumption of covariance analysis (Levene, 1960). The results showed the significance level of all four variables of divided attention (p = 0.86), selective attention (p= 0.23), reaction time (p= 0.07), and working memory (p= 0.09) in the experimental group with the Gagne's model was higher than 0.05. Thus, the assumption of variances was established to perform an analysis of covariance.

In order to investigate the effect size of the Gagne's model of instructional design on the attention level of students with ADHD, a multivariate analysis of covariance (MANCOVA) was conducted. Attention has three subscales: divided attention, concentrated attention, and reaction time. A one-way MANCOVA is applied to evaluate whether there are any statistically significant differences between the adjusted means of three or more independent (unrelated) groups, having controlled for a continuous covariate. MANCOVA was performed when Levene's test, and Box's M were

insignificant. According to the results, the Box's M statistic (8.82) at the F value of 0.72 was not significant at the given error level (0.65), so the null hypothesis was not rejected. This means that the covariance matrices are equal between the groups. To test the hypothesis, the Wilks' lambda statistic was used. Regarding the Wilkes lambda statistic (P=0.05), the hypothesis of the similarity of population means based on the dependent variables for the control and experimental groups was rejected.

Table 4.
Results of MANCOVA of the Effect of Gagne Instructional Model on Attention

Model	Variables	Sum Of Squares	Df	Mean Of Squares	F	*P*
Pretest		394.203	1	394.203	3.572	0.047
group	Divided Attention	22.347	1	22.507	4.276	0.048
	Selective Attention	13.282	1	12.082	6.557	0.018
	Reaction Time	17.165	1	17.165	8.552	0.009

The results of the post-test intergroup effects test with decreasing the pretest effect in the above table show a significant difference between the means of the experimental and the control groups in the subscales of divided attention, selective attention, and reaction time. The mean scores of the experimental and control groups in Table 4 show that Gagne's model of instructional design improved divided attention, selective attention, and decreased reaction time.

In order to examine the second hypothesis of the research regarding the effect of the Gagne's model of instructional design on the capacity of working memory, one-way ANCOVA was used (Table 5).

Table 5.
Results of One-way ANCOVA of the Effect of Gagne's Model of Instructional Design on Working Memory Capacity

Model	Sum Of Squares	Df	Mean Of Squares	F	Sig	Etha Coefficient
Pretest	585.205	1	583.227	3.632	0.050	0.158
Group	577.856	1	577.856	3.396	0.047	0.152

The results of inter-group effects of post-test by decreasing the effect of pre-test in the Table 5 show a significant difference between the two means of the experimental and the control groups. Examining the mean scores of the experimental and control groups shows that Gagne's model of instructional design leads to the increased capacity of working memory in the students with ADHD.

Discussion

The first hypothesis of the research considered the effect of the Gagne's model of instructional design on the attention level of students with attention deficit hyperactivity disorder. Findings showed that the Gagne model affects the attention level of students with ADHD. The results are consistent with the results of previous studies (Alloway & Lepere, 2021; Chen, 2002; Darwazeh, 1993; Korpa et al., 2020; Madani et al., 2017; Mazzocco & Hanich, 2010). It is common today for students to fail to acquire capabilities and skills that should be transferred to real life. The most critical factor in the effectiveness of Gagne's model compared to the conventional models is attracting students' attention to the steps of recalling past learning and transferring learning. Due to the nature of memory, active recall is crucial and effective in learning. When one remembers the materials, they can access previously encoded and memorized information from the past. Recalling past learning and transferring learning by creating opportunities for practice and applying what has been learned in different situations increase students' attention levels. The best way to increase students' attention span is to practice continuously (Telch et al., 2020). Poor performance of attention is one of the characteristics of children with attention disorders, and it seems that the processes of the memory system and mental storage of these people are problematic and it seems that in the crucial years of elementary school, focusing on attention is a prerequisite for learning. In general, based on the hypothesis of brain plasticity, it can be explained that the possible effects of Gagne's model of instructional design are due to cognitive exercises and repetition of these exercises. We can assume that the exact mechanism underlying the experimental formulation processes produces spontaneous or guided improvements in these disorders. Thus, well-designed cognitive training in

executive actions can improve the performance of children with ADHD (Alloway & Lepere, 2021; Lai & Chang 2020).

In Gagne's method, students are introduced to the experiment by playing a video of how things are done or doing experiments or installing pictures in the classroom, and arrange conversations about the effects and results of scientific experiments. Then the teacher has students to pay attention to their perceptions and correct possible flaws, thus strengthening the level of selective attention in students. Also, because in the Gagne's model of instructional design, the teacher guides the students during all stages of education to solve their problems, students who have difficulty performing the performance are given more training and, if possible, use different methods. Therefore, the amount of divided attention in the students increases gradually. Moreover, in the Gagne's model, at the end of the session the teacher announces that students should be able to explain how the task is done, and the teacher reminds the students of their past learning and other functions they have learned and can do correctly, and wants the students to point out how they must perform which increases recall rate and students' reaction time.

The second hypothesis of the research was related to the effect of the Gagne's model of instructional design on the working memory capacity of students with ADHD. Findings of the study showed that the Gagne's model effectively increases the working memory capacity of these students. This finding is consistent with that of Valian (2019), Spaulding (2017), Mazzocco and Hanich (2015), and Madani et al., (2017). In explaining this result, it should be stated that the most critical factors for the effectiveness of Gagne's model in the amount of working memory capacity of students with ADHD should be sought in the steps of attracting attention, informing about learning goals, and providing guidance. The teacher uses the attention-attracting step to stimulate the students' emotional dimension and motivation. As information is transferred from the senses to the sensory and working memory, learners must be prepared to learn the content by adopting strategies. Also, the teacher should not assume that students know the educational goals (Mazzocco & Hanich, 2017). The teacher should clearly state the learning objectives for the students, and the content and skills should be understood within the framework of the learner's prior knowledge. For this purpose, the teacher in Gagne's model of instructional design increases the capacity of working memory by creating a link between the steps of recalling past learning and providing educational materials and uses the step of providing a learning guide to enrich learning and activate learners' memory. Student activity during the instruction and relating new content to students ' prior knowledge, while increasing the quality of teaching and instruction, also increases students' working memory capacity (Spaulding, 2017).

Conclusion

As our society moves towards growth and development, recognizing the issues and problems of children who are the future generation of our country is a vital and valuable task. Thus, understanding their problems and helping them to solve the difficulties is of the most critical educational system issues. Providing mental health for children and adolescents helps fulfill their social, mental, and physical plans. Due to the high prevalence of attention disorders and insufficient attention to the consequences of these disorders in children and adolescents, it seems necessary to take the necessary and timely measures. An increasing volume of research has indicated that children with ADHD experience more social problems with peers, siblings, parents, and teachers than their peers without the disorder and that these children have academic issues, including academic failure. Therefore, lack of identification and intervention in children with attention disorders will cause them to have social problems in school, their classmates and family, teachers, parents, and society. Also, in the educational process, they cannot experience academic progress and sometimes these children are more likely to drop out of school.

Moreover, because ADHD is related to a range of other disorders related to memory and attention of students and that the prevalence of this disorder is higher than other disorders, it is crucial to investigate the effectiveness of educational methods in improving this disorder. Given that the educational model has an essential role in students' learning and cognitive processes, teachers can design educational content based on the appropriate model considering students' cognitive functions, including attention and memory especially for students with ADHD.

One of the theories in explaining the effect of the Gagne model on students' working memory is cognitive and neuropsychological theories that have contributed significantly to understanding the mechanism of action of these disorders and have provided much research data to confirm their theory. An essential assumption of cognitive approaches is that successful learners actively make sense of their previous experiences and thought processes about new information. They use executive or metacognitive processes to determine how new information is searched, perceived, and related to previously stored information, selected and recalled. According to this approach, what distinguishes between a skilled and an unskilled learner is the inability of the

unskilled learner to use the executive processes effectively and efficiently (Kast et al., 2011) and linking new and existing content in cognitive construction.

In the Gagne's model of instructional design, students are introduced to the experiments by presenting keywords. After getting acquainted with them, it is their turn to practice the content. Then, students are asked to come to the board, perform the test, and fix the problems. The teacher guides the students in all the previous steps to solve their problems. Students, who have difficulty doing the test should be given more training and, if possible, use different methods. The student's performance (writing exercises and performing tests) is observed, and possible defects are eliminated. Furthermore, in the book, the student receives instant feedback by comparing his test with the book's writing part. In the left corner of the book, there are options for providing feedback by the teacher according to each student's performance using descriptive sentences. In new experiments, students are asked to do the experiments and bugs are also expressed. Students are asked to design, perform, and present new experiments at home, all of which increase students' working memory capacity.

The present study had some limitations. First, all samples were bilingual, so generalizations to monolingual students should be made with caution. Some researchers believe there is a difference in the working memory of monolinguals and bilinguals. However, it seems that when more straightforward tests and tasks are performed that do not require manipulation of information in working memory, both groups operate at the same level, but when more complex tests are performed requiring more cognitive control and inhibition, bilinguals work better.

Considering the results of the study, it is suggested that a similar study be performed on monolingual students and that the results be compared with the results of the present study. In future research, students can be screened based on the types of attention problems, and the effect of educational patterns on each attention problem should be examined. A similar study should be conducted in other cities (except Tabriz) and rural students. According to the research findings, it is suggested that in future studies, Gagne's model of instructional design be used for other neurodevelopmental disorders such as learning and hyperactivity disorders. Also, in addition to using the results of Gagne's model of instructional design, it is suggested to study the actual and daily performance of these people in school and doing assignments. Considering the effect of the Gagne's model of instructional design on the attention and working memory capacity of students with attention disorders, it is suggested that the principles of educational design based on this model be taught to teacher trainees and in teachers' in-service courses and in the implementation phase, the model should be monitored in classrooms to increase the effectiveness of meaningful teaching and learning.

Conflicts of Interest

No conflicts of interest declared.

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