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Improving sustained attention and working memory of Down syndrome patients through Computer-based Cognitive rehabilitation

Abstract

Down syndrome is the most common genetic cause of mental disorder. This disease causes a decrease in sustained attention and working memory in children.
This research determines the effectiveness of computer-assisted cognitive rehabilitation in improving sustained attention and working memory in Down syndrome patients. This research is a semi-experimental design of single-subject designs with multiple baselines. We selected 9 patients with Down syndrome by sampling at convenience, placed then the subjects in three different baselines and randomly entered into treatment the baselines three, five, and seven. We implemented the intervention for 20 sessions. In order to investigate and measure cognitive variables, we evaluated the tests of Wechsler intelligence (direct-inverted digit span), Tower of London, continuous performance, Stroop and Cressi cubes. Statistical visual analysis shows that the score of the subjects has changed in terms of effect size and recovery percentage. The results indicate the effectiveness of cognitive rehabilitation in improving cognitive deficits (working memory and sustained attention) of children and adolescents with Down syndrome.

Keywords: *Down syndrome, Cognitive rehabilitation, Cognitive deficits in working memory, Sustained attention*

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Introduction

From 750 to 1000 chromosomal-genetic disorders that cause mental retardation, Down syndrome (Ds) is the only one documented in terms of research and dates back to the 19th century (Saguin, 1846). Many researches have taken use of Ds as the most common genetic cause of mental disorder (Hudapp, 2008 ;Godfrey & Lee;2018).

Down syndrome is also the only genetic disorder for which life expectancy has doubled in the last 30 years .and associated etiologically with the neurological changes of Alzheimer's disease (Zigman et al., 2007; Castro, Zaman, & Holland;2017). Moreover, this disease is detected at birth and children with Down syndrome represent etiologically a homogeneous group, although one of its most striking features is the progress of recovery (Perera, 1999). According to the clinical studies, the frequency of these symptoms in Iran has been one in 814 live births. If two million people increase annually in the population of our country, on average, about two thousand babies will be born with Down syndrome.

In these children, there are motivational deficiencies towards learning the content of the lessons. These defects depend on the degree of their mental retardation. They may learn harder and even many of them avoid learning opportunities. Children with Down syndrome benefit from simple and elementary problem solving methods for their learning. These children are physically and mentally slower and their mental functioning is often between mild to moderate mental retardation.(Cowan, 2005 ;) Baburamani, Patkee, Arichi, & Rutherford, (2019).

Occupational therapy and rehabilitation are the only efficient and documented treatments that therapists use to treat Down syndrome. Experimental researches have constantly shown that these treatments can reduce disruptive behaviors to a limited extent and improve the physical condition of children and adolescents suffering from this disease (Bittles, & Glasson, 2004) .We must acknowledge that none of the medical and therapeutic interventions directly target the cognitive problems associated with Down syndrome. One of the promising treatments is cognitive rehabilitation, which is successful in the disorders of brain damage, schizophrenia, hyperactivity, speech disorders, MS, Alzheimer's, brain atrophy caused by dementia. This therapy tries to restore the memory, attention, language learning, decision-making, planning, problem solving, and brain's executive functions.

One of the variables of sustained attention is "the ability to direct and focus cognitive activities on specific stimuli . Sustained attention is "a basic requirement for information processing." Therefore, sustained attention is important for cognitive development. working memory as "a set of mechanisms capable of maintaining a small amount of information in an active state for use in ongoing cognitive tasks"(Schworer, Esbensen., Fidler, Beebe, Carle, & Wiley, 2022). Conway, Kahn, Bunting, Wilhelm, and Ingle (2005) defined working memory as "a multicomponent system responsible for the active maintenance of information in the face of ongoing processing or distraction. However, when we restate these definitions as measurement tasks, differences in the conceptualization of working memory become apparent..

In fact, working memory is a mental system that is responsible for the simultaneous acquirement and temporary processing of information to perform a series of complex cognitive tasks such as understanding, reasoning and learning (Baddeley, 1986). Numerous research evidences indicate the very important and decisive role of working memory in learning and performing complex cognitive tasks (Baddeley, Gathercole

and Papagno, 1998; .Based on the model of working memory developed by Baddeley (2000), working memory falls into three components: two storage systems (auditory and visuospatial loop) and a control system (central executive). It seems that the auditory part is responsible for keeping verbal information in the mind, and the visuospatial part covers non-verbal information. As a regulator of working memory, the central executive plays a role in activities such as directing attention and information flow, simultaneous coordination between two or more tasks, and interaction of long-term memory (Beck et al., 2010). According to the abovementioned, this research determines the effectiveness of computer-assisted cognitive rehabilitation in improving sustained attention and working memory of Down syndrome patients.

Research Methodology

The present study is an experimental single-subject design with multiple baselines. In the current research, there are three types of baselines of 3, 5, and 7 weeks. We placed 9 clients in these three types of baselines as shown in Figure 3, and after the end of the baseline, we entered them in treatment. We compare the effectiveness of treatment for each person in relation to his/her own baseline and to other people. We selected all girls and boys with Down syndrome who were studying in exceptional schools in Delfan city and Nazarzadeh exceptional school in Khoramabad in the academic year 2013-14. They constitute the statistical population of this research (16 people). We selected 9 people through sampling at convenience from among the statistical population of children with Down syndrome who are studying in Tolou school of Delfan and Shahid Nazarzadeh school of Khoram Abad. The age range of the sample is 9-17 years.

In order to identify the Down syndrome disorder and the absence of psychotic and organic disorders, generally having the inclusion criteria and not having the exclusion criteria, we studied the client's medical records. Moreover, to rule out hearing and ergonomic problems, we also asked the subject's medical history from the school counselor and the mother. A clinical psychologist conducted Kessler's test to determine the range of intelligence.

Research tools

1. Cogniplus software

Schuhfried created in 2006 this software for training cognitive functions and used the multimedia. In the software, the researcher asks clients to apply what they have learned in their daily life. This software has sections for working memory functions, direct attention, sustained attention, information processing, problem solving and selective attention.

2. Direct digit span

The experimenter reads a set of single-digit numbers randomly and the subject repeats the numbers in the same order. The series of numbers initially has two digits and after each time a digit is added to the chain of numbers until it reaches a maximum of seven digits. The test is stopped when the child repeats a chain incorrectly twice. The child does not receive any feedback during the test. The experimenter scores performance as the total number of correctly recalled series. Gathercole et al. reported the test-retest validity of digits span by 0.81 and 0.68 for 4-5-year-old children .This test has been widely usable to measure the phonemic circuit of working memory.

3. Reverse digit span

The method of performing this test is the same as the direct digits span, except that the child must remember the digits in the reverse order of their presentation. The experimenter scores the test as the number of correct recalls. The use of this test has been successful in 6- and 7-year-old children and even in 4-year-old children. It has a high correlation with central executive scales and its test-retest reliability is 0.62.

4. Stroop computer test

The Stroop task is a classic laboratory model for assessing selective attention. This test assesses selective attention, or the capacity to pay attention to features of a stimulus and ignore task-irrelevant features. This test has two parts:

The first part consists of the computer-based presentation of four colors (yellow, red, blue and green) in the form of a circle. 50 colored circles are presented, randomly for each of the four colors (yellow, red, blue and green). Each circle appears indefinitely. The subject's task is to press the same color of the indicated circle on the computer keyboard. The goal is to find out if the client can recognize colors and has the ability to read. The second part presents words with correspondent and non-correspondent colors. 48 words that are correspondent with color and 48 words that are not correspondent with color are presented randomly (yellow, red, blue, and green) for 2 seconds on the computer screen. The distance between two stimuli is 800 thousandths of a second. The subject's task is to pay attention only to the color of the word, regardless of the meaning of the words. For example, the word blue is written in green and the subject must press the green key. In scoring this test, the experimenter calculates the subject's reaction time, the number of color naming errors (error announcement) and omission for both types of correspondent and non-correspondent stimuli and the interference score. Siegrest (1997, quoted by Rezaei, 2000) reports the test-retest reliability of the reaction time for the third part by 0.86.

5. Continuous performance test

It is a most common laboratory tool in the measurement of care and is widely used in the assessment of hyperactivity with attention deficit. Researchers prepared it for therapeutic and

research purposes. In all forms, the subject must pay attention to a relatively simple set of visual or auditory stimuli and give his response by pressing a key when the target stimulus appears. In most recent researches, visual stimuli are displayed for a short time on the computer screen and the subject must respond to the target stimulus by pressing one of the keys on the keyboard. In the Persian form of the test, a Persian number or picture is a stimulus, and 30 stimuli (20%) are target stimuli and the remaining 80% are non-target stimuli. The duration of presentation of each stimulus is 200 thousandths of a second and the interval between 2 stimuli is one second. The duration of the test is 200 seconds, including the training phase that takes place for the subject's understanding better before the main phase.

This test scores two types of omission error and commission error. An omission error occurs when a subject fails to respond to the target stimulus and indicates that the subject has difficulty understanding the stimulus. This type of error is interpreted as a problem in the sustained attention and indicates inattention to the stimuli. A commission error occurs when the subject responds to a non-target stimulus. This type of response indicates a weakness in impulse inhibition and is interpretable as a problem in impulse control or impulsivity.

In this test, the computer program counts these two types of errors. Moreover, it calculates the number of correct answers and the subject's reaction time to the stimulus. A study conducted by Dr. Hadianfard et al found that the Persian form of the Continuous Performance Test (CPT) has suitable validity and reliability. In their study, the reliability coefficient (Test-Retest) of different parts of the test was between 52% and 93%. The validity of the test was done with the method of Validity criterion by comparing the normal group (30 primary school boys) and the ADHD group (25 primary school boys). Statistical comparison of the average of the two groups in different parts of the test showed a significant difference in the performance between these two groups ($p < 0.001$). The results of this research are in line with previous researches in other countries.

6. Tower of London test

This test is one of the important tools for measuring the action of planning and organizing (Krikorian et al., 1994, Lezak et al., 2004,). Since the computer-based implementation of this test could have many advantages, including accuracy in execution, accurate measurement of the results, the number of correct and incorrect items, as well as accurate time measurement of the steps, we prepared the initial computer-based version of this test based on the Delphi programming language at the Sina Behavioral-Cognitive Sciences Research Institute. The goal of this test is for the subject to use his maximum ability and get the best performance quickly. Before performing the test, one should ensure the skill of using the computer mouse. After entering the personal information of each subject in the relevant section, the experimenter shows the screen to the subject and says this is a problem-solving test. In this test, you have to move colored beads (green, blue, red) and place them in the right place, with the minimum necessary movements to make the shape of the sample. Then the test shows the example part to the individual. At this stage, the test allows the person three times to solve the problem and the person must solve the example according to the instructions with the minimum necessary moves. Then it tells the subject that, given 12 problems like the example, you have to make the shape of the example with the minimum necessary movements. The person has three times to solve each problem. After success at each stage, the next problem is provided to the individual. The scoring method in this test is such that in appropriate to the effort of the person for solving the problem the score belongs to him/her. This test is one of the important tools for measuring the executive functions of the brain, planning and organization. Since the implementation of this test is computer-based, it will have many advantages, including accuracy, accurate measurement of the results, like the number of correct and incorrect items, as well as accurate timing of the steps.

The purpose of this test is for the subject to use his/her maximum ability and achieve the best performance quickly. In this test, the person must make the shape of the sample by moving the colored beads (green, blue, and red) and putting them in the right place with the minimum necessary movements. People who pass this test have the ability to solve problems, plan, evaluate and make high decisions within the specified time.

This test can be also useful for neuropsychologists as a tool to measure frontal lobe function and diagnose disorders such as schizophrenia.

7. Cressi cube test

It is a computer-assisted test where there is a screen with 9 dark rectangles on it. The arrow goes on each of the rectangles and lights up. After a few seconds, the subject must light up the same rectangles. First, two rectangles are lit, and then another rectangle is added in each presentation to reach 6. The test ends if the subject lights up mistakenly the series of rectangles twice. Performance is the total number of correctly recalled series. The test-retest validity of Cressi span is 0.53 .

Research procedure

First, a psychiatrist conducted diagnostic interview with the students to identify the Down syndrome disorder and the absence of psychotic and organic disorders. Clinical psychologists conducted Children's Kessler test to determine the range of intelligence. We placed the male and female students with Down syndrome and lacking exclusion criteria in different baseline conditions. We placed Clients 3 by 3 in three

types of baselines of 3, 5 and 7 of measurement points of dependent variables. We chose randomly the method of selecting subjects in three types of baselines. In each baseline, we obtained the working memory variable score by calculating the scores obtained in the subscales of direct digit span and Cressi inverted digit span.

We recorded the problem-solving test by the Tower of London test score. We calculated the variable of selective attention with the number of errors and responses of omitting correspondent and non-correspondent stimuli in the Stroop test. In the same way, in the baselines, for sustained attention and information processing, we recorded the continuous performance of the subjects by the score of the computer-based test. Then the subjects entered the design with different baselines. In this way, the first, second and third subjects entered the treatment after three measurement points of the dependent variable, the fourth, fifth and sixth subjects after five measurement points of the dependent variables and the seventh, eighth and ninth subjects entered the treatment after seven measurement points of the dependent variables. The number of intervention sessions is 20 sessions of 45 minutes. Each client practiced rehabilitation programs for working memory, direct attention, problem solving, sustained attention, information processing and selective attention with timed divisions. After the intervention, we measured the dependent variable for each subject at the end of the session. One month after the end of the treatment of the subjects, we collected again the score of the dependent variables.

The treatment process: The first group of subjects received the following treatments in the first session. 1) sustained attention 2) concentration and alertness 3) listening to the ringing of the exercises given to this group. It was the same for five sessions. In each session, based on the hierarchical nature of the software, the subject's level of training increases. After the 5th session, we tested the subjects by Stroop, continuous performance, Cressi cubes, digit span, Tower of London. We still evaluated the other six subjects with the above tests, six to ten treatments per session in addition to homework. We also tested the sustained attention, concentration and vigilance, listening to bells, direct and visuospatial attention. After the ten treatment sessions, we re-evaluated the subjects, and then from sessions 11 to 15, in addition to the four types of (sustained, focused, selective, divided) attention, we added to them the motor-visual and memory tasks. After the 15th session, we tested the subjects with Stroop tests, continuous performance, Cressi cubes, digit spans, and Tower of London. In sessions 15 to 20, we implemented all the above items on the subjects. After the 20th session, we re-evaluated the subjects. After a week of follow-up, we performed the test of Stroop, continuous performance, Cressi cubes, number spans, and Tower of London.

Second group: When the subjects of the first group entered the treatment, we still evaluated the second group. In the 3rd treatment session, the first group and the second group entered the treatment after 5 evaluation sessions. The treatment process and assignments are the same as the first group, and the evaluations are after the 5th, 10th, 15th, 20th session. After a week of follow-up, we performed the tests of Stroop, continuous performance, Cressi cubes, digit span, and Tower of London.

The third group: When the subjects of the first and second groups entered the treatment, we still evaluated the third group. In the session 7 of the first group and session 5 of the second group, the third group entered the treatment after 7 evaluation sessions. The treatment process and assignments are the same as the first and second groups, and the evaluations occur after the 5th, 10th, 15th, 20th session. After a week of follow-up, we performed the tests of Stroop, continuous performance, chair cubes, digit span, and Tower of London. We should note that at the beginning of each training program, we give necessary explanations to the subjects.

Restoration treatment pack or computer-assisted cognitive rehabilitation

We performed the Cognitive restoration by Cogniplus software. In this program, we asked clients to apply what they have learned in daily life in exercises. Rehabilitation training took place in 20 sessions of 45 minutes three times a week.

Working memory: several cars come in different rows. The subject must remember the place of each of them. Cars disappear after a while. The subject should say whether the cars have been displaced or not. If it has occurred, he/she should press the Enter key, otherwise, another key with Nein written on it. Different images come one after the other. In level one to three, the subject must compare each image with the previous image. If there is a repetition, he/she should press the confirmation key, and if it is not similar to the previous image, he/she should press the Ctrl key. From level three onwards, different images come one after the other and the subject must compare the current image with the two previous images.

Sustained attention: as for the sound of the bell and the sound of the pager, the subject must press the Enter button. The game has different levels, and the level changes automatically as the subject's level increases. The motorcycle moves and hits the seven obstacles that the subject must hit the Enter key as soon as he/she sees the obstacle. The game has 18 stages, the subject starts from stage 1. With good performance, the level of the game changes and goes to a higher stage.

In order to review and analyze the behavioral data, we used in this research the visual analysis method, Cohen's d size, recovery percentage (in cases where the goal is to increase

behavior) and average reduction percentage (in cases where the goal is to decrease behavior).

Results

Visual analysis of the graph can examine the change in the intensity of symptoms based on three procedures (surface, slope or trend of changeability). Graph (1) and table (1) show that in group one three baselines recorded for the subjects are highly variable. Variability in scores is often observable in the intervention phase, and in the follow-up phase, the created level remains relatively constant. As we can see, when the first group entered the treatment, the second and third groups are still in the baseline stage, and when the changes in the first group begin, we observe no change in scores in the other two groups. The change in the level, in all three groups, started after entering the treatment, and before that, there were changes to the extent of the changes that are specific to children with Down syndrome.

This decrease in reaction time and increase in correct response have manifested themselves since the initial sessions. The percentage increase in the correct answer and the effect size for all cases were high, and the percentage decrease in reaction time was moderate. In all nine cases, we do not observe a direct slope of decrease in reaction time and increase in correct response in early sessions; but with the increase of treatment sessions, we see this direct slope in decreasing the amount of reaction time and increasing the correct answer. This issue is associated with the variability of attention in people with Down syndrome; but with increasing sessions, we see that this slope reaches a balanced level without fluctuations. From among the nine cases, case one in the 15th session has managed to give correct answers to all the stimuli. Thus, hypothesis one is confirmable. The details of the analysis of the above cases are as follows: Table (1) shows the percentage of reduction in behavior and the size of the effect of treatment on sustained attention deficit (continuous performance test).

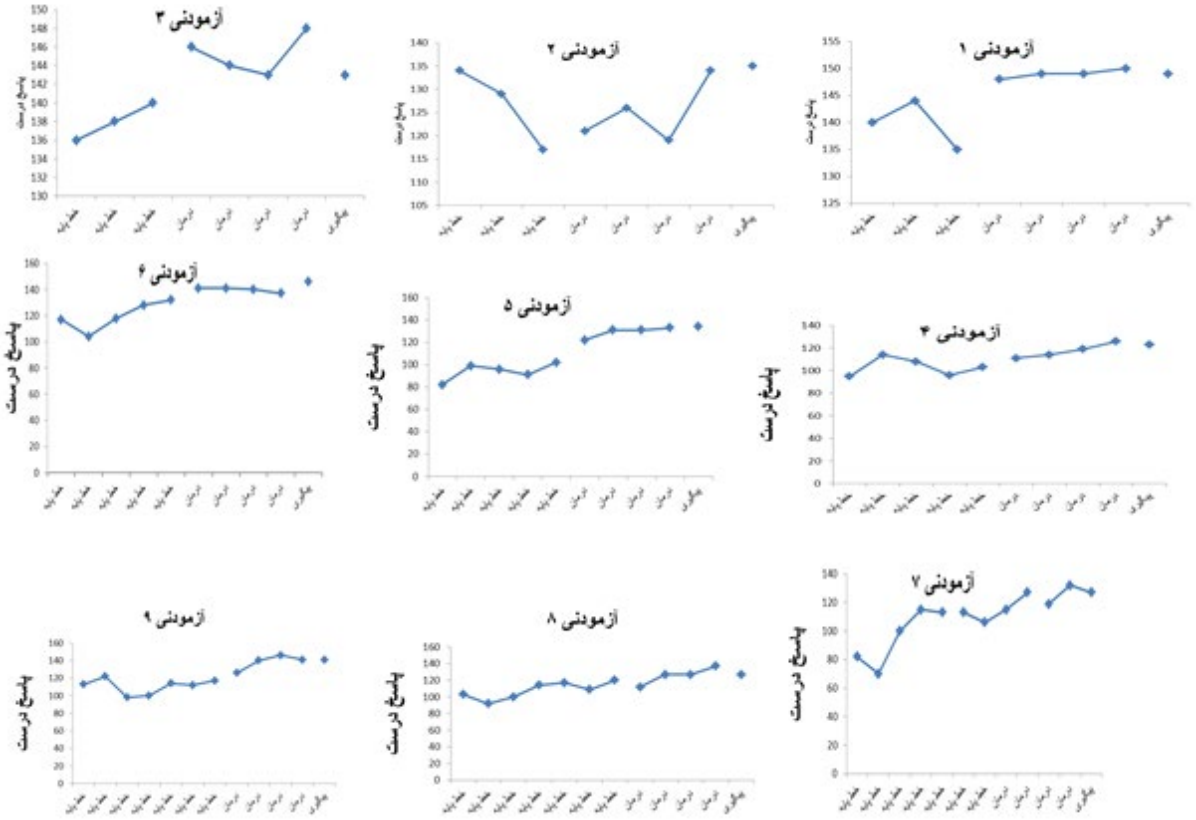

Chart 1: Change in severity of symptoms based on three procedures

Table 1: (continuous performance)

Subject 1	Correct	Reaction time
MPI	6	3
MPR	7	3
D	1.78	1.06
Subject 2		

MPI	1	3
MPR	1	3
D	-0.26	-0.43
Subject 3		
MPI	5	-
MPR	5	-
D	1.81	-0.07
Subject 4		
MPI	12	38
MPR	14	62
D	1.48	1.2
Subject 5		
MPI	27	11
MPR	38	12
D	1.91	0.74
Subject 6		
MPI	14	5
MPR	17	5
D	1.62	-0.83
Subject 7		
MPI	19	8
MPR	23	7
D	1.33	-0.26
Subject 8		
MPI	14	17
MPR	17	21
D	1.42	0.96
Subject 9		
MPI	20	8
MPR	25	7
D	1.78	-0.52

Graphs (2) and table (2) show that in group one three baselines recorded for subjects have little variability. Variability in scores is often observable in the intervention phase, and in the follow-up phase, the created level remains relatively constant. As we can see, when the first group entered the treatment, the second and third groups are still in the baseline stage, and when the changes in the first group begin, we observe no change in scores in the other two groups. The change in the level, in all three groups, started after entering the treatment, and before that, there were changes to the extent of the changes that are specific to children with Down syndrome. From among the 9 cases under study, all cases had an increase in direct attention and reverted digits during the treatment period. This increased direct attention has manifested itself from its initial sessions. The percentage increase in the frequency of inverted numbers and the effect size for all cases were high.

In all nine cases, we do not observe a straight slope of increasing reverted span in the early sessions; but with the increase of treatment sessions, we see this direct slope in the increase of the reverted span. This issue is associated with the variability of direct attention in people with Down syndrome; but with increasing sessions, we see that this slope reaches a balanced level without fluctuations. From among the nine cases, the fourth case in the 15th session has managed to give correct answers to 3 cases in the reverted span. Thus, hypothesis one is confirmable. The details of the analysis of the above cases are as follows:

Visual analysis of the graph can examine the change in the severity of symptoms based on three procedures (surface, slope or trend of changeability). Graphs 1, 2, 3 show that in group 1 three baselines recorded for the subjects have little variability. Variability in scores is often observable in the intervention phase, and in the follow-up phase, the created level remains relatively constant. As we can see, when the first group entered

the treatment, the second and third groups are still in the baseline stage, and when the changes in the first group begin, we observe no change in scores in the other two groups. The change in the surface, in all three groups, started after entering the treatment, and before that, there were changes to the extent of the changes that are specific to children with Down syndrome. From among 9 cases under study, all cases increased during the treatment period in direct and reverted digits of visual memory. This increase has manifested itself since the initial sessions. The percentage increase in audio-visuospatial memory span and the effect size for all cases were high (Table 2).

In all nine cases, we do not observe a direct slope of increase in auditory-visuospatial memory span in early sessions; but with increasing treatment sessions, we see this direct slope. This issue is associated with the variability of working memory in people with Down syndrome; but with increasing sessions, we see that this slope reaches a balanced level without fluctuations.

From among the nine cases, the fourth case has increased the capacity of auditory-visuospatial memory. Thus, the sixth hypothesis is confirmable. The details of the analysis of the above cases are as follows:

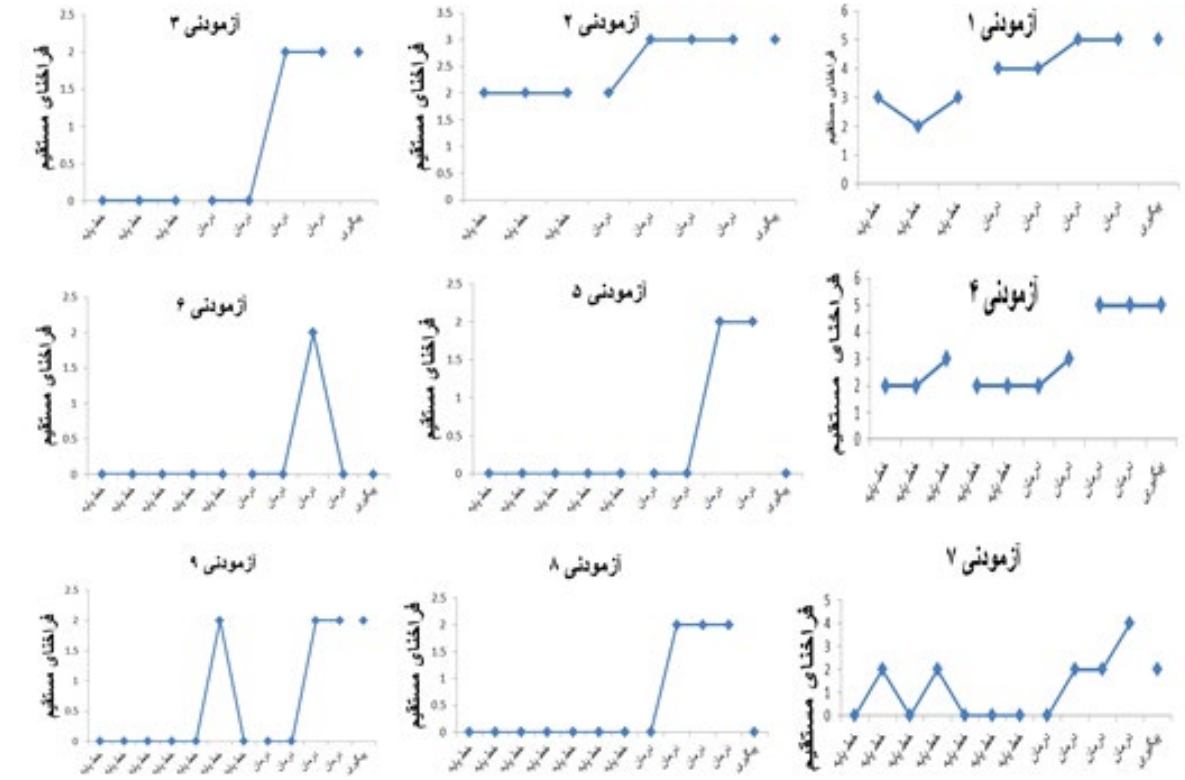

Chart 2: Change in severity of symptoms based on three procedures
Subject, direct arena

Table 2: (Digit span)

	Subject 1		Subject 2		Subject 3	
	Direct	Reverted	Direct	Reverted	Direct	Reverted
MPI	41	100	27	100	100	100
MPR	69	-	38	-	-	-
D	1.78	1.8	1.52	1.52	1.11	0.71
	Subject 4		Subject 5		Subject 6	
	Direct	Reverted	Direct		Direct	Reverted
MPI	41	84	100	-	100	100
MPR	70	525	-	-	-	-
D	1.3	1.82	1.2	-	0.8	0.8
	Subject 7		Subject 8		Subject 9	
	Direct	Reverted	Direct		Direct	Reverted

MPI	71	100	100	100	71	100
MPR	250	-	-	-	250	-
D	1.09	1.68	1.68	1.3	0.8	1.3

Discussion & Conclusion

Out of 750 to 1000 chromosomal-genetic disorders that cause mental retardation, Down syndrome (Ds) is the only documented one in terms of research and dates back to the 19th century (Seguin, 1846). Etiologically, it is associated with the neurological changes of Alzheimer's disease (Zigman et al. 2007). According to clinical studies, the frequency of these syndromes in Iran has been one in 814 live births.

In general, these children have motivational deficiencies towards learning the content of lessons. They are slower in terms of physical and mental development, and their mental functioning is often between mild to moderate mental retardation. In the clinical trial, researches have evaluated extensively language factors, adaptive skills, learning and memory, motor skills and behavior, and in this research. There are many evidences of memory problems, especially in the spatial tests of orientation, which are about the hippocampus function in the DS population (Carlesimo et al., 1997, Hyde et al., 2001, Nadel, 2003).

The results showed that computer-assisted cognitive rehabilitation in children with Down syndrome improves sustained attention. In fact, by looking at the subject effect size of the correct answer index of these children after the intervention, we can infer that the changes are due to the experimental application. These results are in line with the findings of Wangels Park's research conducted in 2001 on 359 subjects. Its results showed that their attention performance improved significantly after computer-assisted therapy.

The results showed that computer-assisted cognitive restoration (rehabilitation) treatment improves working memory in children with Down syndrome. The analysis showed that computer-based cognitive rehabilitation in children with Down syndrome improves working memory. In fact, by looking at the effect size of the subject of the reaction time index of these children after the intervention, we can infer that the changes are due to the experimental application. These results are consistent with the research findings of Alloway et al. (2006) in the treatment of adults with brain lesions by microcomputer.

Ethical considerations: Ethical principles are fully observed in this article. Including the principle of confidentiality, confidentiality of personal information, consent and informed participation in the research.

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Conflict of interest: The authors declare that there is no conflict of interest in the present study.

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