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Nearest Transfer Effects of Working Memory Updating Training: An Experimental Study on Students With, and without Learning Disabilities

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Abstract

Working memory considered as a core of human cognition and it plays a vital role in academic performance, so working memory impairment is one of the main causes of learning disabilities. Studies indicated that working memory can be enhanced through training, and the training effects can be transferred to other cognitive functions. In the current study, a total of (45) 7th-grade students were divided into three groups: the mathematics learning disabilities (MLD) group (n=14), the reading learning disabilities (RLD) group (n=13), and the normal group (n=18). All the groups completed an adaptive computerized updating training in (5) weeks with a total of (20) sessions, and each session lasted for (20) minutes. Before and after training all of the groups were required to complete an automated version of complex span tasks (operation span task + symmetry span task). Results indicated that normal children performed significantly in the majority of complex span tasks than learned disabled children (LDs), results also indicated that updating training improved working memory efficiency for the MLD group markedly higher than the RLD group, and the normal group was the lowest group that benefited from the training. This study provides experimental evidence that working memory updating training could attenuate impairments of working memory for LDs to some extent, and causes near-transfer effects.

Key words: Complex span tasks; learning disabilities; updating training; working memory

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1. Introduction

Working memory (WM) refers to a cognitive system that is responsible for the temporary storage and manipulation of information (Baddely & Hitch, 1974; & Baddeley, 2000). It considered as a core of human cognition. Working memory is related to many cognitive functions such as reasoning skills (Sus H-M et al.,2002; Ren, 2021). Problem-solving and intelligence (Alloway, 2006; Unsworth et al., 2009; & Engle, 2010). Academic achievement (Carretti et al., 2005 & Pelegrina et al., 2015). Language comprehension and reading (Gathercole & Pickering, 2000; & Conway et al., 2003). It also predicts performance in mathematics (Ang et al., 2015). According to Baddeley's multicomponent model, working memory consists of four components: the central executive, phonological loop, visuospatial sketchpad, and episodic buffer (Baddeley, 86, 2000, 2007). The central executive considered as a supervisory component, it controls the attentional system, regulates the coordination between other subcomponents, and relations between working memory and long-term memory. The phonological loop stores verbal and phonetic information, it has a limited storage capacity such as a visuospatial sketchpad that is responsible for storing visual and spatial information for a brief time also. The relatively new subcomponent that has been added to WM system is the episodic buffer, which is responsible for integrating information with a variety of codes to form meaningful chunks, episodic buffer forms an interface between long-term memory and working memory (Baddley, 2000, 2007; Unswoth & Engle, 2008; Unsworth et al., 2009 & Chen et al., 2017).

Recently, working memory deficit has been approved as a critical factor associated with learning disabilities (Zhang et al, 2018). Many studies indicated that WM efficiency is impaired in individuals with learning disabilities. For examples, a meta-analytical study by (Swanson et al, 2009) that computed (578) effective cases and realized that individuals with reading disabilities were disadvantaged compared with their normal peers in working memory measures that depend on the simultaneous processing and storage of digits with sentences. In a study of (Cai Li & Deny, 2013) on 111 Chinese students with a mean age = 11.63 and suffered from mathematics learning disabilities, they revealed that: these students showed impairments in central executive, they also showed difficulty in congruency between storage tasks and information processing tasks, they have deficits in manipulation and holding of visuospatial information due to impairment in visuospatial sketchpad. the study also showed that MLD students have deficits in both sentence span task and number span task. (Ahmed, 2021) Measured both verbal and visuospatial working memory adding to selective attention for MLD students with mean age = 12.59 and their normal peers. The two groups were matched for age and IQ, the results indicated that the performance of MLD students is lower than normal on operation task that is used to measure verbal working memory capacity, and symmetry span task that is used to measure visuospatial working memory capacity. In visual selective attention, normal children were better than MLD in correct responses (accuracy), but there was no significant difference between them in response time (speed).

Learning disabilities refer to impairments in an individual efficiency to acquire the suitable skills needed for learning mathematics, writing, and reading to be at the same level as other people of similar intelligence, education, and chronological age (Zhang et al, 2018). The prevalence of LDs among school children ranged between (10-14%) (Hendrisken et al., 2007). On the other hand, a variety of studies have suggested that children with learning disabilities showed observable impairments in working memory updating. (Cornoldi, Drusi, Tencati, Giofre & Mirandola, 2012) indicated that children with RLD experience deficiencies in problem solving and updating tasks, specifically in word updating tasks (Pelegrina et al, 2015). But there is no significant difference between normal children and MLD children in the word updating task, otherwise, there is a significant difference for normal children in the number updating task compared with MLD children (Iuculano, Moro, & Butterworth, 2011).

Working memory updating is a core component of the central executive; recently there is a great focus on it in the field of WM research (Zaho et al., 2011 & Klinberg, 2010). Working memory updating can be defined as a fundamental cognitive skill that enables WM to monitor, modify and replace temporarily stored information with other related information for a task at hand in order to adapt to new environmental demands (Morris & Jonies, 1990; Collette & Venderlinden, 2002; Belacchi, Carretti & Cornoldi, 2010; Chen & Li, 2007; Friedman et al, 2006, & Chein, et al., 2017). According to the previous definition; working memory updating plays a crucial role in learning by allowing relevant information to get into the working memory system and prevent irrelevant and distracting information. Working memory considered as a plastic component, therefore it can be enhanced through WM updating training specifically in individuals with WM impairments (Gathercole et al., 2019; Karbach, Strobach, & Schubert, 2015, Titz & Karbach, 2014). With intensive training for WM, the benefits gained have been found from preschool years to late adulthood, and for individuals with a wide range of developmental disorders (Karbach & Verhaeghen, 2014; Sonuga-Bake et al., 2013).

n-back training is considered a complex task, and it activates many executive processes because it consists of two congruent tasks: visuospatial task, and auditory-verbal task, in n-back tasks participants face a lengthy sequence of items and judge for each item whether it matches the items presented (n) positions back. n-back task activates many executive processes such as working memory updating, monitoring ongoing performance, and inhibition of irrelevant items, the simultaneous between different modalities tasks activates more processes such as dividing attentional resources (Salminem, Strobach & Schubert, 2012; & Gathercole et al., 2019). Outcomes of WM training varied widely, some studies indicated the near transfer effects, some studies indicated both near and far transfers, otherwise some studies have found no signs of transfer (Alloway, Bibile, & Lau, 2013; & Colom et al., 2013). Near transfer effects in the context of WM updating training refer to improvements in other functions or abilities closely related to updating such as working memory, while far transfer refers to enhancements in other functions or abilities more distantly related to updating, but still share some cognitive components with the trained domain (updating), such as fluid intelligence, attention (Dahlin et al., 2008; Klinberg et al., 2005; Artuso et al., 2019; Jaeggi et al., 2008). In Zhang et al. (2018) the results revealed that working memory updating training can enhance updating ability in children with learning disabilities, and training effects transfer to mathematical performance in such children. In a study by (Fellman et al., 2020) (4) weeks adaptive WM training group (n=273) receiving external strategy instruction, and a traditional group trained without strategy instruction (n=118) finally passive control group (n=67). Results indicated that both training groups showed transfer effects to untrained n-back tasks variants after (3) training sessions only, but it extended to all untrained n-back task variants at post-test after (12) training sessions. (Ang, 2015) applied running span keep track paradigms on (111), 7 years old children diagnosed with mathematics learning disabilities and impairment in WM they divided on (4) groups: updating training group, Cogmed training group, active control group, and passive control group. results indicated that updating training produced only marginal enhancements relative to control, and it was sustained and transformed to significant differences (6) months past training, Cogmed training produced substantial improvements at immediate posttest, but converted to marginal at delayed posttest. Enhancements don’t transfer to mathematics nor WM tasks that differed widely from those used during training for both types of training. (Chen et al., 2017) studied the effects of WM updating training on (64) children with LDs were divided equally into training or control groups. Adaptive running WM updating was applied to the training group for (20) days, WM capacity, fluid intelligence, and math score have been measured before and after training. Results indicated that WM updating could mitigate the cognitive deficits of LDs and improve the previous measurements.

From the previous, we can conclude that in general, working memory-updating training can improve other cognitive abilities especially those most related to the nature of training, there are inconsistencies in results concerned with far transfer effects.

A topic of current research concerns the following questions:

- Does performance on complex span tasks differs between MLDs/ RLDs and Normal?
- Can WM updating training (n-back) enhance the efficiency of working memory as measured by complex span tasks?.

2. Methods

2.1 Participants

A total of 45 seventh-grade students (29) boys, and (16) girls, with a mean age of (12.32), and a standard deviation (SD)= 0.485. Children were selected from middle school in Dakhlyia governorate (Egypt), the sample consists of (18) normal students, (13) with reading learning disabilities (RLD), and (14) with mathematics learning disabilities (MLD). The children with learning disabilities (LDs) were those who have difficulties in reading or mathematics performance, the learning-disabled children were diagnosed as the following:

(1) Raven's Progressive Matrices was applied, and the students who have IQs less than (88) (percentile rank less than 25) were excluded.

(2) Examining the school psychologist's records to exclude students with some health disorders, and students belonging to socio-economically disadvantaged families.

(3) Student scores in math and reading were obtained for the first term of the academic year 2022/2023 from the actual paper school score without adding degrees of activities to reflect the real student's achievement.

(4) The children's scores in IQ, mathematics, and reading were converted into (Z-scores), the students diagnosed as MLD by subtracting the standard score of IQ Z-scores and standard scores of mathematics (Math Z-scores), if the subtraction result (discrepancy result) exceeded more than (1) standard, and by the same way (RLD) students were diagnosed.

Finally, the three groups MLD/RLD, and Normal children were enrolled in pre and post-test, between them, the intervention updating training was applied.

2.2 Training Task (updating training)

In the current study, an adaptive computerized n-back training was developed specifically to suit the aims of the study, and to induce the updating ability of WM. In the first stage (Mono-n-back), there was a separation between auditory stimulus and visuospatial stimulus, the trainee has to respond by clicking on the right arrow in the keyboard in case of listening to the same Arabic number twice in a row as the shape indicated.

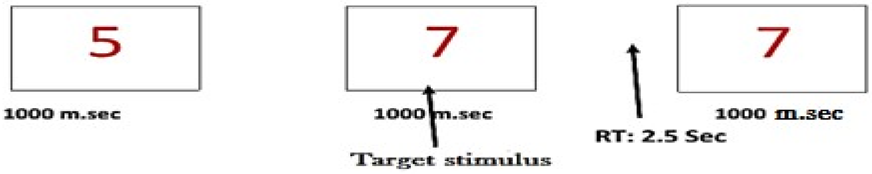

Figure 1. An example on Auditory Mono-n-back

In addition, by clicking on the left arrow in keyboard in case of seeing the same image in the same location twice in a row as the shape indicated.

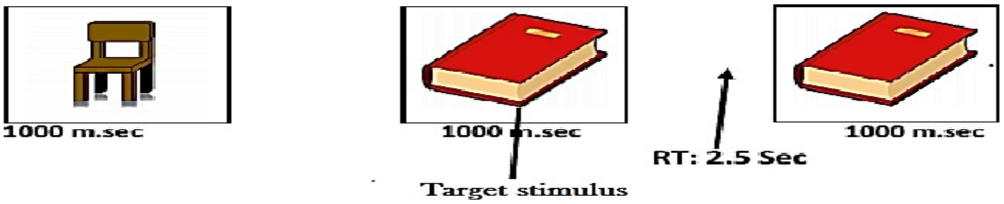

Figure 2. An example on Visuospatial Mono-n-back

The visual stimuli appear on a grid 3*3 in its outer frame because its center has a fixed point as the shape indicated

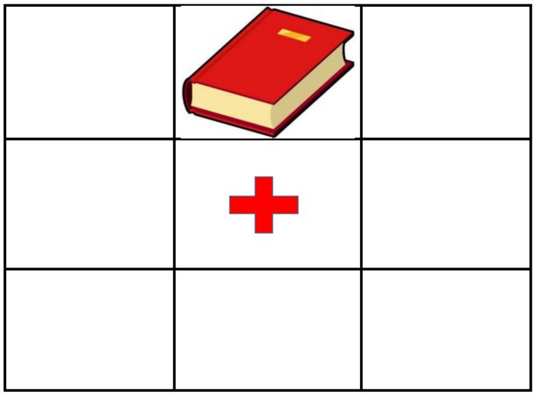

Figure 3. Screenshot for the training during visual Mono-n-back stage

In this first stage, the presentation time of every stimulus (auditory or visual) is 1000 milliseconds, and response time (RT)=2.5 sec, visual stimuli locations varied randomly. If the trainee completed this Mono-n-back by 75% of correctness or exceeded; he or she transferred to the Dual-n-back automatically, in Dual-n-back the auditory and visual stimuli presented simultaneously, this stage varied between Dual-1-back to Dual-2-back to Dual-3-back according to the performance of the trainee. In Dual-1-back two target stimuli are presented a row without separation, but in Dual-2-back the trainee has to respond by clicking on the suitable arrow only if the two target stimuli appeared (for visual stimulus) or heard (for auditory stimulus) separated by one distracted stimulus, in Dual-3-back the trainee has to respond by clicking on the suitable arrow only if the two target stimulus appeared or heard separated by (2) distracted stimulus. The trainee transferred between stages automatically if he or she completed it with a ratio of correctness equal to or exceeding 75%. In each stage, there are many sub-stages that differed in presentation time of stimulus that begins with 1000m.sec and transfers to 800m.sec and also differed in response times (RTs) that begin with (3) seconds and end with 2.5 seconds.

Transfer tasks

Automated Operation Span Task (AOSpan)

This task used for assessing verbal working memory efficiency, it consists of two simultaneous tasks, in the first, participants have to solve a series of math operations, then indicate whether a presented answer is correct or not by clicking on the words yes or no (V.I the math operation presented in Arabic digits). For example, 2+4-3= 2 Yes or No

In Arabic نعم أم لا 2 =3-4+2

The presentation time for each math operation is 3 seconds, after that, they saw an Arabic letter and have to store it, the letter presentation time is 1200 milliseconds. Three trials of each list length (2-5) were presented for a total of 42 tasks, after 2 to 5 such processing and storage presentations a recall grild is presented, and participants have to click on the letters they stored during the trial in the correct serial order, the recall grid consists of 12 unrelated Arabic letters (ي – ل – س – ص – ط – د – ر- ج – ف – ب – م – و), the order of list length varied randomly. The score is computed automatically according to the sum of letters recalled in the correct serial position, regardless of whether the entire trial was recalled correctly (capacity), and the number of correct math operations (processing). There are three practice tasks before proceeding to the real tasks:

1- Storage task only;
2- Processing task only;
3- Processing-Storage task, that is identical to real tasks in its nature.

Presentations times for letters (storage) and math operation (Processing) are computed in an independent pilot study, statistical reliability and validity were calculated, Pearson's correlation coefficient between (AOSpan) and Raven's Standard Progressive Matrices (RSPM) is 0.685* (significant at 0.01 level), Kuder-Richardson formula 21 used for assessing reliability, the value is 0.925* (significant at 0.01 level). (Conway et al., 2001; Redick et al., 2012; Unsworth et al., 2009, 2013).

Automated Symmetry Span Task (AsymSpan)

This task is used for assessing visuospatial working memory efficiency; it consists of two simultaneous tasks. In the first, participants saw an 8*8 matrix with some squares filled in black, and the rest white (unfilled), participants have to decide whether this matrix is symmetrical about its vertical axis or not, the pattern was symmetrical half of the time, directly after that, participants were presented with 4*4 grid all of its squares is white (unfilled) except one filled with red, participants ordered to store the red square location, at recalling participants recalled the sequences of red square locations in the same order they appeared by clicking on the cells of an empty matrix. The presentation time for the processing task is 3 seconds, and the presentation time for the storage task is 1500 milliseconds, these times were determined in an independent pilot study. Like the operation span task, three trials of each list length 2-5 were presented for 42 tasks, and the order of list length varied in a random arrangement. There are three practice tasks before proceeding to the real tasks:

1- Storage task only;
2- Processing task only;
3- The Processing-Storage task is identical to real test tasks in its nature.

The Score is computed automatically according to the sum of red squares locations in the correct serial position regardless of whether the entire trials were recalled correctly (capacity), and the number of correct matrices (processing). Statistical reliability and validity were calculated, Pearson's correlation coefficient between (AsymSpan) and Raven's Standard Progressive Matrices (RSPM) is 0.554* (significant at 0.01 level), Kuder-Richardson formula 21 was used for assessing reliability, the value is 0.87* (significant at 0.01 level). (Shipstead et al., 2013, 2014; Unsworth et al., 2009, 2013).

2.3 Procedure

All participants in the three groups (MLD/ RLD/ Normal children) were required to complete complex span tasks (operation span task + symmetry span task) before and after training to enable the near transfer effects to be analyzed. Each child in all groups completed an adaptive computerized updating version of the training, the training took (5) weeks with a total of (20) sessions, at a rate of (4) sessions per week, and the duration of every session is (30) minutes, with a total training time equal (600) minutes/10 hours.

3. Results

SPSS version 16.0 was employed for data aggregation and statistical analysis. First, descriptive statistics of working memory efficiency measures (Complex Span Tasks) for each group were calculated in each session.

Table 1. Descriptive statistics for MLD

	Complex span tasks	Mean	SD	N
Post.Test	verbal.capacity.	34.57	5.44	14
	Visual.capacity	26.57	10.30	14
	Total.Capacity	61.14	14.87	14
	Verbal.Processing	26.42	7.52	14
	Visual.Processing	22.92	5.23	14
	Total.Processing	49.35	10.04	14
	Total	36.83	16.74	84
Pre.Test	verbal.capacity	27.00	7.42	14
	Visual.capacity	22.21	9.78	14
	Total.Capacity	49.21	15.00	14
	Verbal.Processing	24.85	9.80	14
	Visual.Processing	19.78	5.80	14
	Total.Processing	44.64	12.70	14
	Total	31.28	15.33	84

	Complex Span Tasks	Mean	SD	N
Post.Test	Verbal.Capacity	34.23	7.27	13
	Visual.Capacity	27.07	10.27	13
	Total.Capacity	61.30	17.08	13
	Verbal.Processing	26.00	6.40	13
	Visual.Processing	21.84	4.14	13
	Total.Processing	47.84	9.29	13
	Total	36.38	17.00	78
Pre.Test	Verbal.Capacity	27.84	7.93	13
	Visual.Capacity	23.23	9.20	13
	Total.Capacity	51.07	15.83	13
	Verbal.Processing	23.07	9.04	13
	Visual.Processing	18.84	5.68	13
	Total.Processing	41.92	12.33	13
	Total	31.00	15.46	78

Table 2. Descriptive statistics for RLD

Table 3. Descriptive Statistics for Normal group

	Complex Span Tasks	Mean	SD	N
Post.Test	verbal.capacity.	37.11	6.88	18
	visual.capacity	27.50	7.04	18
	Total.coacity	64.61	9.65	18

	verbal.processing	33.00	6.99	18
	visual.processing	24.88	4.56	18
	Total.processing	57.88	9.67	18
	Total	40.83	16.89	108
Pre.Test	verbal.capacity	32.05	6.35	18
	visual.capacity	28.11	5.96	18
	Total.coacity	60.16	9.33	18
	verbal.processing	32.88	5.60	18
	visual.processing	23.38	4.08	18
	Total.processing	56.27	8.35	18
	Total	38.81	15.67	108

To investigate the differences in working memory capacity between groups (Normal / RLD / MLD) in pre-test, Independent (T) Samples are calculated for all complex span tasks in order to compare means.

Table 4. Independent (T) samples for complex span tasks in pre-test

measures	Means	groups	T	df	Significance 2-tailed
Verbal Capacity	N= 32.06 MLD=27.00 RLD=27.84	Normal vs. RLD	1.640	29	0.112
		Normal vs. MLD	2.075	30	0.047*
		MLD vs. RLD	0.286	25	0.777
Visual Capacity	N= 28.1 MLD=22.2 RLD=23.2	Normal vs. RLD	1.79	29	0.083
		Normal vs. MLD	2.10	30	0.044*
		MLD vs. RLD	0.278	25	0.784
Total Capacity	N= 60.17 MLD=49.21 RLD=51.07	Normal vs. RLD	1.851	17.97	0.081
		Normal vs. MLD	2.535	30	0.017*
		MLD vs. RLD	0.314	25	0.756
Verbal Processing	N= 32.9 MLD=24.9 RLD=23.07	Normal vs. RLD	3.73	29	0.001*
		Normal vs. MLD	2.92	30	0.007*
		MLD vs. RLD	0.489-	25	0.629
Visual Processing	N= 23.4 MLD=19.8 RLD=18.8	Normal vs. RLD	2.59	29	0.015*
		Normal vs. MLD	2.060	30	0.048*

		MLD vs. RLD	0.424-	25	0.675
Total Processing	N= 23.4 MLD=19.8 RLD=18.8	Normal vs. RLD	3.86	29	0.001*
		Normal vs. MLD	3.116	30	0.004*
		MLD vs. RLD	0.563-	25	0.578

To investigate the efficiency of updating working memory training:

A (2) sessions: pre-test and post-test X (6) tasks (verbal capacity, visual capacity, total capacity, verbal processing, visual processing, and total processing): a repeated measure of variance (ANOVA) was conducted.

For the MLD group, the results indicated the main training (session) effect - F(1,78)=36.813, $P<0.001$, $\eta 2= 0.321$ was significant. The main measures (tasks) effect - F(5,78)=31.950, $P<0.001$, $\eta 2= 0.672$ was significant. The session and task interaction was significant - F(5,78)=2.732, P=0.025, $\eta 2= 0.149$.

For the RLD group, the results indicated the main training (session) effect - F(1,72)=44.969, $P<0.001$, $\eta 2= 0.384$ was significant. The main tasks effect -F(5,72)=27.394, $P<0.001$, $\eta 2= 0.655$, was significant, but session and task interaction was non-significant (F(5,72)=2.010, P=0.087, $\eta 2= 0.123$).

For the Normal group, the results indicated the main training effects - F(1,102)=7.754, P=0.006, $\eta 2= 0.071$, was significant. The main tasks effect - F(5,102)=118.294, $P<0.001$, $\eta 2= 0.853$, was significant, but session and task interaction was non-significant - F(5,102)=2.010, P=0.152, $\eta 2= 0.075$.

For more analysis, T-tests for paired samples between post and pre-test were calculated for each task in complex span tasks as the following table indicated

Table 5. T-Test for paired samples (post-pre) test in complex span tasks

Groups	Tasks	T	df	Significance
MLD	Verbal Capacity	8.84	13	0.000*
	Visual Capacity	1.370	13	0.194
	Total Capacity	3.516	13	0.004*
	Verbal Processing	0.925	13	0.372
	Visual Processing	2.785	13	0.015*
	Total Processing	2.493	13	0.027*
RLD	Verbal Capacity	5.132	12	0.000*
	Visual Capacity	1.745	12	0.106
	Total Capacity	3.781	12	0.003*
	Verbal Processing	1.631	12	0.129
	Visual Processing	2.264	12	0.043*
	Total Processing	2.786	12	0.016*
Normal group	Verbal Capacity	3.050	17	0.007*
	Visual Capacity	0.343	17	0.736
	Total Capacity	2.076	17	0.053
	Verbal Processing	0.076	17	0.940
	Visual Processing	1.175	17	0.256
	Total Processing	0.748	17	0.465

Finally, profile plots for the performance of complex span tasks were drawn for every group (MLD/RLD/Normal) at the pretest and posttest.

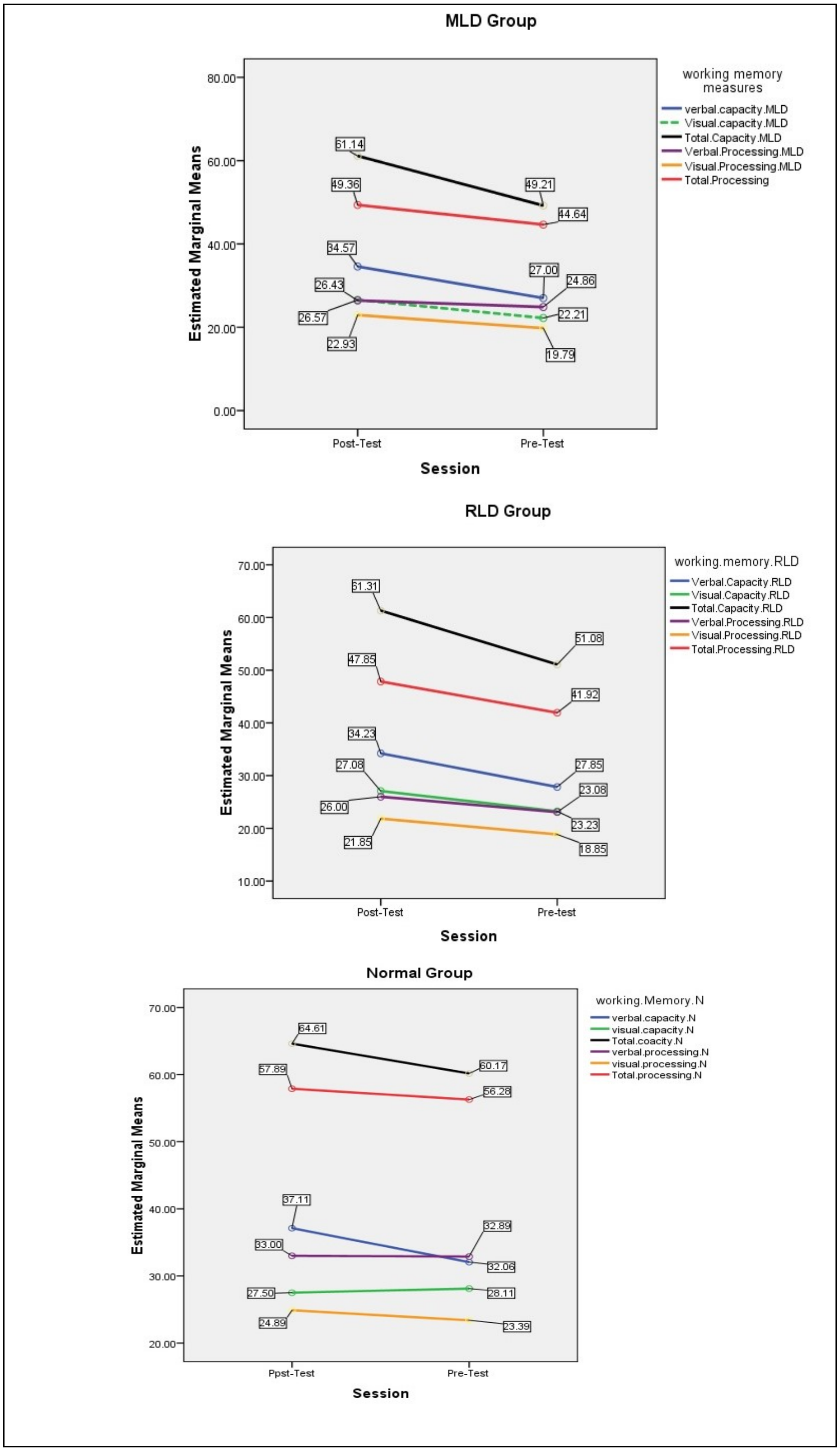

Figure 4. The performance Plots of Complex Span Tasks at pre and posttest for each group

4. Discussions

The purpose of the current study was to investigate whether working memory efficiency differs between normal students and their peers with MLD and RLD, also it mainly concerned with investigating whether WM updating training could improve working memory efficiency and cause near transfer effects. The results indicated obviously that the normal group was better in performance in the majority of tasks in complex span than learning disabled groups. In the pretest normal children's scores were significantly better on verbal capacity, visual capacity, total capacity, verbal processing, visual processing, and total processing compared with mathematics learning disabilities (MLD). Normal children's scores were significantly better compared with Reading learning disabilities (RLD) on verbal processing, visual processing, and total processing, but there were no significant differences in verbal capacity, visual capacity, and total capacity. Comparing between two learned disabled groups (MLD/RLD) indicated that there were no significant differences on all complex span tasks in the pretest.

Many studies presented multiple indicators that specific learning disabilities are related to impairments in working memory, and there is strong evidence that individuals with reading learning disabilities have impairments in phonological processing and storage, they have also impairments in executive functions. Research that concerned individuals with mathematics learning disabilities, indicated that they have obvious deficits in central executive and visuospatial sketchpad (Mahler & Schundart, 2009). Deficits in central executive cause a decrease in the ability of individuals with mathematics learning disabilities to activate appropriate information quantum in long-term memory (LTM) that needed for integration with phonological and visuospatial information (Masoura,2006).

Working memory efficiency was investigated for two main types of academic learning disabilities: MLD & RLD; these deficits in their working memory are realistic and logical especially in the field of processing because of acute impairment in the central executive. These deficits also continued in the posttest but there was a decrease in intensity, this may due to the effectiveness of training, and the learned disabled students were more benefited from this training compared with their normal peers. As for the effect of updating working memory training on working memory efficiency as measured by complex span tasks. The training program that was applied represents the ability of the individual to deal with two congruent tasks: one of them is a visuospatial task and the other is an auditory-verbal task. This simultaneously activates working memory updating and the ability to monitor information in order to replace old information with new (Owen, Macmillan, Laird , EdBullmore, 2005; Salminem, Strobach & Schubert, 2012). In complex span tasks that were used to evaluate the efficiency of working memory, individuals had to store relevant information in an active state and at the same time manipulate other information (Swanson & Zehang, 2014). This congruency between demands (storage + processing) had to activate memory updating and monitoring. Therefore, complex span tasks and N-back shared the same general working memory domain, from this perspective, the MLD group scores on Complex span tasks in the current study had been improved after (5) weeks and (20) session of training. However, in the RLD group, there was no significant difference between the post and pretest in the interaction between the session and tasks, but there was significance in the main session effect and main tasks effect. In detail there were significant differences in sub-tasks of complex span for the RLD group between post and pretest as proved by calculating T-values of paired samples as the following: T-test for verbal capacity = 5.132, $P > 0.001$, T-test for visual processing = 2.264, $P=0.043$, T-test for total capacity = 3.281, $P= 0.003$, and T-test for total processing = 2.786, $P= 0.016$. this relative improvement may be due to the nature of WM updating training(n-back) that gives great interest in visuospatial working memory that is more related to mathematics compared with reading, so the MLD group benefited from the training greater than the RLD group. For the normal group, there was no significant difference in working memory efficiency between post and pretest, this may be due to the efficiency of their working memory before training.

Conclusion

The current study indicated that WM updating training could transfer near effects, and cause mitigate impairments of working memory in individuals with learning disabilities to some extent, it also indicated that MLD children highly benefited from this training more than their peers with RLD, and normal groups. So future studies have to replicate studying the effects of WM updating training on reading disabilities.

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