The effect of memory training on children with learning difficulty
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Background
Learning is a step by step process that relies on successful completion of individual learning activities for accumulation of knowledge. Failure of working memory (auditory and visual memory) can lead to inattentive behavior. The end result is frequently lost learning opportunities and so slow rates of educational progress.

Objective
The aim of this study is to adapt and apply the ‘no-glamour memory’ training program to suit the Egyptian learning disabled children to outline a program for training and test its effectiveness.

Patients and methods
This study was conducted on 20 school-age children complaining of learning difficulty and memory problems who were attending the Unit of Phoniatrics, Department of Otorhinolaryngology, Alexandria Main University Hospitals. All children were assessed using the protocol of assessment of learning difficulties and memory deficits and were reevaluated after a period of 3–6 months of training.

Results
In the present study, there was significant improvement of the studied group in the different tests such as Stanford Binet Intelligence Scale, childhood attention and adjustment survey, Arabic dyslexia assessment test, and test of memory and learning 2nd ed., after therapy.

Conclusion
Memory training can have an effect on domain-general cognitive mechanisms; thus, these results benefit multiple areas of cognition and learning.

Keywords:
auditory memory, learning difficulty, memory training, the ‘no-glamour memory’ training program, working memory

Introduction
The human memory system is responsible for processing information in the brain making them accessible for later use [1]. Memory is the process of encoding, storing, consolidating, and recovering information [2]. Functionally, human memory systems can be classified into three systems: short-term sensory storage, short-term memory, and long-term memory [3,4].

In normally developing children, performance on working memory (WM) span tasks is a crucial indicator of academic accomplishment [5]. Poor academic accomplishment is one of the key attributes of children with WM deficiencies [6].

The connection of WM to different parts of academic achievement emerges primarily from its restricted capacity. Even individuals with normal WM assets have a very confined WM capacity [7]. The WM capacity determines to a great extent the individual’s ability to effective learning. Additionally, competent use of its resources is essential for all individuals, not merely those with WM deficits [8].

Three common approaches to rehabilitation have been applied for memory deficits: remedial, compensatory and a combination of the two. Remedial interventions aim at improving weaknesses and deficiencies. Making use of one’s cognitive advantages and strengths, compensatory interventions attempt to overcome the deficit, hence diminishing its effect on learning, whereas combined interventions integrate both the remedial and compensatory approaches to address memory deficits. Most effective interventions reported in literature are multidimensional in nature with the potential of additive effects from different methods [9].

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An effective training program aiming at improving memory skills was needed to help children with learning difficulty and memory deficits. The ‘no-glamour memory’ training program has straightforward, flexible materials that teach alternative approaches to learning, rely on multiple kinds of input (e.g. visual, auditory and kinesthetic), and are also fun for students [10].

The rationale of this study is to adapt and apply the ‘no-glamour memory’ training program to suit the Egyptian learning disabled children to outline a program for training and test its effectiveness in an attempt to help students overcome their memory deficits in a multimodality approach and improve their learning process.

Patients and methods

Pilot study
This study was conducted on 10 randomly chosen children. The ‘no-glamour memory’ program was applied after translation and modification to the Arabic language.

Assessment of learning difficulty
Twenty school-age children were assessed using the protocol of assessment of learning difficulties and memory deficits and were reevaluated after a period of 3–6 months of training. Assessments included the following:

(1) Psychometric evaluation:

| Table 1 Mean age, sex, type of school, grade, and preferred hand for the studied group |
|-------------------------------|---------------------------------|-------------------------------|
| Age (years)                      | Means±SD                        | KS test                      |
| Mean±SD                         | 8.67±1.92                       | D=0.184, P=0.075 (NS)         |
| KS test                         | 13 (65.0)                       | D=0.091, P=0.200 (NS)         |
| Sex [n (%)]                     | male 10 (50)                    | D=0.091, P=0.200 (NS)         |
| Females 7 (35.0)                | D=0.091, P=0.200 (NS)           |
| Grade [n (%)]                   | KG2 5 (25.0)                    | D=0.091, P=0.200 (NS)         |
| KG1 3 (15.0)                    | D=0.091, P=0.200 (NS)           |
| KG3 2 (10.0)                    | D=0.091, P=0.200 (NS)           |
| KG4 2 (10.0)                    | D=0.091, P=0.200 (NS)           |
| KG5 1 (5.0)                     | D=0.091, P=0.200 (NS)           |
| KG6 0 (0.0)                     | D=0.091, P=0.200 (NS)           |

KS, Kolmogorov–Smirnov test; P≥0.05, statistically no significant difference.

The ‘no-glamour memory’ training program [10]

(1) The program is divided into two main sections:
(a) Auditory memory section:
   (i) Rehearsing and subvocalizing.
   (ii) Chunking.
   (iii) Creating lists and taking notes.

Table 2 Results of the Stanford Binet Scale before and after therapy

|                                | Before therapy | After therapy | Test of significance (P value) |
|--------------------------------|----------------|---------------|--------------------------------|
| Verbal IQ                      |                |               |                                |
| Means±SD                       | 91.90±6.38     | 94.85±7.68    | Z_{WSR}=2.862 (P=0.004*)        |
| KS test                        | D=0.164, P=0.167 (NS) | D=0.091, P=0.200 (NS) |                                |
| Abstract IQ                    |                |               |                                |
| Means±SD                       | 92.85±9.44     | 91.55±10.22   | Z_{WSR}=1.412 (P=0.158, NS)     |
| KS test                        | D=0.105, P=0.200 (NS) | D=0.110, P=0.200 (NS) |                                |
| Short-term memory              |                |               |                                |
| Means±SD                       | 78.55±9.94     | 82.20±11.71   | Z_{WSR}=1.889 (P=0.059, NS)     |
| KS test                        | D=0.162, P=0.181 (NS) | D=0.119, P=0.200 (NS) |                                |
| Visual memory                  |                |               |                                |
| Means±SD                       | 84.80±11.93    | 86.35±11.61   | Z_{WSR}=0.886 (P=0.376, NS)     |
| KS test                        | D=0.127, P=0.200 (NS) | D=0.195, P=0.045* |                                |
| Auditory memory                |                |               |                                |
| Means±SD                       | 74.95±11.70    | 82.85±10.60   | Z_{WSR}=3.264 (P=0.001*)        |
| KS test                        | D=0.182, P=0.080 (NS) | D=0.144, P=0.200 (NS) |                                |
| General IQ                     |                |               |                                |
| Means±SD                       | 84.50±6.37     | 87.65±7.39    | Z_{WSR}=1.914 (P=0.056, NS)     |
| KS test                        | D=0.119, P=0.200 (NS) | D=0.115, P=0.200 (NS) |                                |

KS, Kolmogorov–Smirnov test; WSR, Word selective reminding. P≥0.05, statistically no significant difference. *P<0.05, statistically significant difference.
(iv) Graphing and charting.
(v) Identifying key concepts.
(vi) Linking and associations.
(vii) Visualizing.
(viii) Paraphrasing.

(b) Visual memory section:
(i) Chunking.
(ii) Acronyms and silly sentences.
(iii) Drawing and defining.
(iv) Graphing and charting.
(v) Identifying key concepts.
(vi) Visualizing.
(vii) Paraphrasing.
(viii) Saying, tracing, writing, and drawing sounds.

**Results**

Twenty school-aged children participated in this study (mean age: 8.67 years, range: 5.33–11.17 years)

| CD (conduct problems) | Pretherapy results | Post-therapy results | Test of significance (P value) |
|-----------------------|--------------------|----------------------|-------------------------------|
| Mean±SD               | 73.65±18.81        | 71.00±17.41          | \( Z_{\text{WSR}} = 1.068 \) (\( P = 0.285 \), NS) |
| KS test               | \( D = 0.129 \), \( P = 0.200 \) NS | \( D = 0.139 \), \( P = 0.200 \) (NS) |
| ADHD (attention deficit hyperactivity disorder) | | |
| Mean±SD               | 77.15±26.94        | 70.65±26.88          | \( Z_{\text{WSR}} = 2.989 \) (\( P = 0.003^* \)) |
| KS test               | \( D = 0.215 \), \( P = 0.016 \) (NS) | \( D = 0.117 \), \( P = 0.101 \) (NS) |
| H (hyperactivity)     | | |
| Mean±SD               | 73.40±19.70        | 68.25±18.89          | \( Z_{\text{WSR}} = 3.122 \) (\( P = 0.002^* \)) |
| KS test               | \( D = 0.192 \), \( P = 0.051 \) (NS) | \( D = 0.166 \), \( P = 0.151 \) (NS) |
| ADD (attention deficit disorder) | | |
| Mean±SD               | 76.45±21.98        | 70.20±21.42          | \( Z_{\text{WSR}} = 3.463 \) (\( P = 0.001^* \)) |
| KS test               | \( D = 0.156 \), \( P = 0.020 \) (NS) | \( D = 0.215 \), \( P = 0.016 \) (NS) |
| I (impulsivity)       | | |
| Mean±SD               | 65.75±26.31        | 64.40±25.38          | \( Z_{\text{WSR}} = 0.632 \) (\( P = 0.527 \), NS) |
| KS test               | \( D = 0.179 \), \( P = 0.092 \) (NS) | \( D = 0.181 \), \( P = 0.086 \) (NS) |
| N (inattention)       | | |
| Mean±SD               | 79.85±23.09        | 76.70±17.88          | \( Z_{\text{WSR}} = 2.487 \) (\( P = 0.013^* \)) |
| KS test               | \( D = 218 \), \( P = 0.014 \) (NS) | \( D = 0.154 \), \( P = 0.200 \) (NS) |

KS, Kolmogorov–Smirnov test; WSR, Wilcoxon signed rank test. *\( P < 0.05 \), statistically significant difference.
Table 4 Comparison between the studied groups pre-and post-therapy as regards TOMAL-2

| Core battery (verbal subsets)       | Pretherapy results | Post-therapy results | Test of significance (P value) |
|-------------------------------------|--------------------|----------------------|--------------------------------|
| Memory for stories                  |                    |                      |                                |
| Mean±SD 5.60±2.85                   | 9.55±2.11          | Z_{WSR}=3.945        |
| KS test D=0.162, P=0.175 (NS)       | D=0.118, P=0.200 (NS) | P=0.000*            |
| Word selective reminding            |                    |                      |                                |
| Mean±SD 8.95±2.89                   | 11.80±2.65         | Z_{WSR}=3.136        |
| KS test D=0.111, P=0.200 (NS)       | D=0.230, P=0.007 (NS) | P=0.002*            |
| Object recall                       |                    |                      |                                |
| Mean±SD 8.40±3.76                   | 10.95±3.75         | Z_{WSR}=3.507        |
| KS test D=0.137, P=0.200 (NS)       | D=0.160, P=0.191 (NS) | P=0.000*            |
| Paired recall                       |                    |                      |                                |
| Mean±SD 7.25±2.95                   | 10.05±3.02         | Z_{WSR}=3.612        |
| KS test D=0.214, P=0.017 (NS)       | D=0.174, P=0.116 (NS) | P=0.000*            |
| Core battery (nonverbal subsets)    |                    |                      |                                |
| Facial memory                       |                    |                      |                                |
| Mean±SD 9.85±4.23                   | 12.25±3.75         | Z_{WSR}=3.642        |
| KS test D=0.169, P=0.137 (NS)       | D=0.227, P=0.0008 (NS) | P=0.000*            |
| Abstract visual memory              |                    |                      |                                |
| Mean±SD 10.95±3.85                  | 13.60±3.69         | Z_{WSR}=3.302        |
| KS test D=0.148, P=0.200 (NS0       | D=0.165, P=0.160 (NS) | P=0.001*            |
| Visual sequential memory            |                    |                      |                                |
| Mean±SD 9.65±2.94                   | 12.30±3.08         | Z_{WSR}=3.913        |
| KS test D=0.138, P=0.200 (NS)       | D=0.111, P=0.200 (NS) | P=0.000*            |
| Memory for location                 |                    |                      |                                |
| Mean±SD 8.05±2.56                   | 9.75±2.63          | Z_{WSR}=3.107        |
| KS test D=0.158, P=0.200 (NS)       | D=0.212, P=0.019 (NS) | P=0.002*            |
| Supplementary (verbal subsets)      |                    |                      |                                |
| Digits forwards                      |                    |                      |                                |
| Mean±SD 7.40±2.30                   | 9.50±2.26          | Z_{WSR}=3.436        |
| KS test D=0.219, P=0.013 (NS)       | D=0.188, P=0.63 (NS) | P=0.001*            |
| Letters forward                      |                    |                      |                                |
| Mean±SD 8.15±2.28                   | 9.60±2.41          | Z_{WSR}=3.306        |
| KS test D=0.226, P=0.009 (NS)       | D=0.248, P=0.002 (NS) | P=0.001*            |
| Digits backwards                     |                    |                      |                                |
| Mean±SD 8.25±2.34                   | 10.35±1.84         | Z_{WSR}=3.001        |
| KS test D=0.143, P=0.200 (NS)       | D=0.138, P=0.200 (NS) | P=0.003*            |
| Letters backward                     |                    |                      |                                |
| Mean±SD 7.70±1.30                   | 9.20±1.67          | Z_{WSR}=3.684        |
| KS test D=0.205, P=0.028 (NS)       | D=0.198, P=0.040 (NS) | P=0.000*            |
| Supplementary (nonverbal subsets)   |                    |                      |                                |
| Visual selective remembering        |                    |                      |                                |
| Mean±SD 8.60±3.52                   | 10.50±3.12         | Z_{WSR}=3.623        |
| KS test D=0.175, P=0.108 (NS)       | D=0.164, P=0.167 (NS) | P=0.000*            |
| Manual imitation                    |                    |                      |                                |
| Mean±SD 9.40±2.76                   | 11.35±2.16         | Z_{WSR}=3.315        |
| KS test D=0.144, P=0.200 (NS)       | D=0.168, P=0.140 (NS) | P=0.001*            |
| Verbal delayed recall               |                    |                      |                                |
| Memory for stories delayed          |                    |                      |                                |
| Mean±SD 5.65±2.87                   | 9.75±1.94          | Z_{WSR}=3.818        |
| KS test D=0.117, P=0.200 (NS)       | D=0.201, P=0.033 (NS) | P=0.000*            |
| Word selective reminding delayed    |                    |                      |                                |
| Mean±SD 9.70±3.18                   | 12.80±2.09         | Z_{WSR}=3.419        |

(Continued)
There was a statistically significant difference between verbal IQ in the studied group before therapy and after therapy ($P = 0.004$). A statistically significant difference was found in the auditory memory subset of short-term memory before therapy and after therapy ($P = 0.001$) (Table 2 and Figure 1). The studied group showed statistically significant difference regarding ADHD, H (hyperactivity), attention-deficit disorder, and N (inattention) components of the childhood attention and adjustment survey before therapy and after therapy ($P = 0.003$, 0.002, 0.001 and 0.013, respectively). However, there was no statistically significant difference regarding CD (conduct problems) and I (impulsivity) (Table 3 and Figure 2). All items and indices of the TOMAL-2 showed statistical significant difference ($P \leq 0.01$) in the studies group before and after therapy (Table 4a–g and Fig. 3a–g). The at-risk quotient obtained from the Arabic dyslexia assessment test was significantly lower after therapy in the studied group. Farquharson et al. [13] described

### Table 5 Comparison between the studied group before therapy and after therapy regarding Arabic dyslexia assessment test

| ADAT | Before therapy | After therapy | Test of significance ($P$ value) |
|------|----------------|---------------|----------------------------------|
| ARQ  | $1.65 \pm 0.71$| $1.23 \pm 0.61$| $Z_{(WSR)} = 3.631$ |

ADAT, Arabic dyslexia assessment test; ARQ, at risk quotient; KS, Kolmogorov–Smirnov test; WSR, Wilcoxon signed rank test. *$P < 0.05$, statistically significant difference.
Figure 3

(a) Box and whisker graph of test of memory and learning 2nd ed. (TOMAL-2) core battery (verbal subsets) scores in the studied group before (pre) and after (post) therapy. The thick line in the middle of the box represents the median, the box represents the interquartile range (from 25th to 75th percentiles), and the whiskers represent the minimum and maximum after excluding outliers (black-filled circles) (numbers indicate the serial number of the case in the master table). (b) Box and whisker graph of TOMAL-2 core battery (nonverbal subsets) scores in the studied group before (pre) and after (post) therapy. The thick line in the middle of the box represents the median, the box represents the interquartile range (from 25th to 75th percentiles), and the whiskers represent the minimum and maximum after excluding outliers (black-filled circles) (numbers indicate the serial number of the case in the master table). (c) Box and whisker graph of TOMAL-2 supplementary (verbal subsets) scores in the studied group before (pre) and after (post) therapy. The thick line in the middle of the box represents the median, the box represents the interquartile range (from 25th to 75th percentiles), the whiskers represent the minimum and maximum after excluding outliers (black-filled circles) (numbers indicate the serial number of the case in the master table). (d) Box and whisker graph of TOMAL-2 supplementary (nonverbal subsets) scores in the studied group before (pre) and after (post) therapy. The thick line in the middle of the box represents the median, the box represents the interquartile range (from 25th to 75th percentiles), and the whiskers represent the minimum and maximum after excluding outliers (black-filled circles) (numbers indicate the serial number of the case in the master table). (e) Box and whisker graph of TOMAL-2 verbal delayed recall subsets scores in the studied group before (pre) and after (post) therapy. The thick line in the middle of the box represents the median,
comparable outcomes in children after training for memory deficits, specifically for expressive language, nonword repetitions, and rapid automatic naming. These attainments are generated by enhanced access to stored lexical information and may be improved attention. Gill et al. [14] found that providing visual instructions to children as a rehearsal procedure resulted in effective and enduring change in their capability to follow these instructions.

The present study demonstrated a pattern of improvement regarding auditory memory subset of short-term memory in the studied group. This is comparable to the work of Holmes et al. [15] who found significant improvement in verbal short-term memory, response inhibition, and complex reasoning in their group of trainees.

Klingberg et al. [16] documented that trained cases manifested posttreatment advancement in visual-spatial and sound-related verbal WM, in addition to a generalization to other more complex reasoning skills. These findings indicate that intensive training of the plastic neural systems underlying these components results in augmentation of their standard function [17,19]. On the contrary, intense and prolonged rehabilitation programs may rather encourage the evolution of either WM approaches that countervail the defects in primary processes or the volitional control of attention [15].

There was no improvement of abstract IQ (nonverbal intelligence) in the studied group in the current study. Numerous research reported robust association between WM and intelligence [17,19]. Nevertheless, and in spite of the research attempts made until now, the elements underlying their robust association continue to be perplexing. Many studies could not prove such a relationship. Holmes et al. [15] stated that some cognitive assessments such as individual tests of fluid cognitive ability remained uninfluenced by training.

Our current study showed a consistent pattern of reduction in the severity of behavioral symptoms of ADHD (especially inattention and hyperactivity) in the studied group. Beck et al. [20] reported improved parent and teacher ratings after memory training. The improvements were maintained at 4-month follow-up. Klingberg and colleagues suggested that WM training may ameliorate behavioral symptoms of inattention, at least according to parents’ judgments [19,21].

In the present study, the studied group showed a consistent pattern of improvement regarding all subsets and indices of the TOMAL-2 as compared with the control group. Both auditory and visual memories showed improvement in the studied group. This finding was not illustrated by the visual memory subset of short-term memory on the Stanford Binet scale. This might
be because of the comprehensive and more detailed nature of the assessment using the TOMAL-2. The findings relate to the study by Holmes et al. [17], which detected a considerable improvement of WM scores in most children who finished a rehabilitation program. This improvement was observed both over the duration of training as well as for an additional period of 6 months after training has been concluded. Improvement extended to include some untrained WM assessments, especially those involving either the storage of visuospatial material or the simultaneous storage and manipulation of either visuospatial or verbal material.

The current study shows a consistent pattern of improvement in the at-risk quotient of the Arabic dyslexia assessment test in the studied group. Current proof suggests that memory training can generate compelling attainment on untrained WM tasks [19,22]. However, the degree to which WM learning is passed on to untrained tasks in diverse fields, such as phonological skills, is not yet confirmed [23]. Loosli et al. [24] suggested the presence of shared procedures among WM and reading. This is manifested by the appreciable improvement of reading skills following WM training in normally developing children. Dahlin [25] found that better reading comprehension was associated with improving WM but not with word decoding or orthographic verification. However, Holmes et al. [15] found no effect of memory training on word identification, yet an improvement in mathematical problem-solving skills. These findings indicate that many different processes, including encoding, covert maintenance, attention, updating, interference resolution, and controlled memory search are integrated in the compound WM span tasks. One or more of these processes may be affected by training. Consequently, transfer to different cognitive measures relies additionally on the influence of training on different processes [15].

**Conclusion**

The Arabic version of ‘no-glamour memory’ remediation program is an effective tool for children with learning difficulty.

Domain-general cognitive mechanisms are influenced by memory training; therefore, can benefit multiple areas of cognition and learning.

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Nil.

**Conflicts of interest**

There are no conflicts of interest.

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