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Compensatory and Rehabilitative Cognitive Training Improves Executive Functions and Metacognition

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Abstract

Purpose: The main objective of the present paper is to boost executive functions and meta-cognition via compensatory and rehabilitative cognitive training.

Methodology: In a randomized controlled trail with pretest, post-test and follow-up assessment, the effects of compensatory and rehabilitative cognitive training via education and personalized practice was studied on the EF and metacognition of 126 secondary students aged 16-18. Participants were assigned randomly into an experimental training group (n=61) using Practical Cognitive Strategy Training (PCST) or a wait-list control group (n=65). PCST (Roshd) consisted of two parts: cognitive strategy awareness and practice for compensatory cognitive training and cognitive exercises for rehabilitative cognitive training. The data was analyzed using repeated measure ANOVA in SPSS 23.

Findings: Results showed a significant difference between experimental and control group in strategy use after twelve sessions of training once a week in a twelve-week period of training and a one-month follow-up assessment ($P \leq 0.001$). The participants also reported some kinds of transfer in the use of learned cognitive strategies to other life activities. Limitations: The study only used practical real life executive functions exercises and let the students choose whether to use training apps or not. The amount of extra training out of training situation was not controlled.

Conclusion: Practical daily-life-based executive functions training can practically enhance executive functions and meta0cognitipon in real life activities.

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1. Introduction

Cognition is referred to as mental activities concerning acquisition, storing, manipulation and use of information and such processes as perception, memory, verbal and visuo-spatial working memories (Alloway, Elsworth, 2012), language, problem solving, decision making, rational reasoning (Wall, 2015) and learning (Marlin, 2013). Cognitive skills contribute to the individual successful life experiences among which are efficient leadership (Mumford, Todd, Higgs, McIntosh, 2016), social interactions, learning and decision making. Cognitive skills and mainly executive functions have proven to have significant effects on human behavior, overall intelligent performance and mental health (Leonard, Abramovitch, 2019). Executive functioning is an umbrella term that incorporates all other cognitive management processes such as inhibitory control, shifting and working memory (Diamond, Ling, 2015). Higher order critical reasoning consisting of inference, explanation, evaluation, self-regulation and interpretation is be specifically defined as the ability to identify the problem, gathering and analyzing data, finding or creating the solution(s) and evaluating and re-defining the execution of the solution when necessary (Wall, 2015), concerns with EF processes. Most scholars agree on three fundamental elements as the core components of executive functions: working memory, cognitive inhibition and cognitive shifting (Qehaja-Osmani, 2013). The most significant component of EF is working memory which is the crucial element in the fluid and crystallized intelligence and is best manifested in academic (Alloway, Elsworth, 2012).

and social performance and is defined as the capacity to process and manipulate information in a short period of time. Working memory is also the most popular model proposed by Baddeley and Hitch (Baddeley, Hitch, 1994) for executive functioning. EF capacity more than IQ scales can predict and positively correlates with the school achievement and consists of some core capabilities such as attention and holding and manipulating information in working memory (Kirk, Gray, Riby, Cornish, 2015), prioritizing, organizing, planning, goal setting, shifting (Melitzer, 2010), inhibition, decision-making, problem solving, autobiographical memory (Fernández-Alcántara, Pérez-García, Pérez-Marfil, Catena-Martínez, et al., 2016). There are also three other areas in executive functions that directly deal with these core capabilities including planning, initiation and monitoring (Chan, Shum, Toulopoulou, Chen, 2008). Processing speed which is an unreplaceable component of a flourishing life style and intelligence (Tyler, 1964) and affects all cognitive skills has a close relationship with working memory span (Brébion, David, Jones, Pilowsky, 2009; Fry & Hale, 1996) and can be enhanced by cognitive training.

There are two approaches toward cognitive training; the remediation, rehabilitation or restorative approach and compensatory approach (Bryce, Lee, Ponsford, & Rossell, 2015). In rehabilitation training participants with some kind of genetic or acquired cognitive impairment undergo a series of training programs that directly address the impaired cognitive process. The latter approach is the compensatory approach which in turn has two types: internal compensation and external or environmental compensation (Bryce, et al., 2015). Restorative approach seeks to improve or treat the deficit by providing some specific and goal-directed exercises designed for the stimulation of neural circuits. Compensatory approaches attempt to aid the impaired cognitive processes via internal strategy education, i.e. self-management, self-monitoring, impulse-control, planning, goal setting and the like; or use of external aids, i.e. alarms reminders, note pads, adapted environment, etc. These kinds of training have been proved to produce acceptable outcomes concerning the targeted issue. The improvements have endured in the follow-up re-assessments; e.g. in multiple sclerosis (Klein, Drummond, Mhizha-Murira, Mansford, et all, 2017), cognitive injuries after TBI (Cicerone, Langenbahn, Braden, Malec, et al, 2011; Stephens, Williamson, Berryhill, 2015; Galetto, Sacco, 2017), schizophrenia (Tan & King, 2013; Bryce, et al., 2015; Saperstein, Kurtz, 2012; Hegde, 2017), after stroke (Gillespie, Bowen, Chung, Cockburn, Knapp, et al., 2015), Parkinson's disease (Adamski, Adler, Opwis, Penner, 2016), and neurodevelopmental disorders (Ahn, Hwang, 2017).

Although there are serious doubts about the transfer effects of these trainings whether computer-based or other types of the training (Sander, Schmiedek, Brose, Wagner, 2016; Souders, Boot, Blocker, Vitale, et al., 2017; Sala, Gobet, 2017; Melby-Lervåg, Redick, & Hulme, 2016; Pennington, Nicolich, & Rahm, 1995; Söderqvist, Nutley, 2017), cognitive training has shown to improve cognitive performance in the targeted cognitive domain especially among those with inherited or acquired cognitive impairments (Ratner, Atkinson, 2015; Sander, et all, 2016; Barban, Annicchiarico, Pantelopoulos, Federici, et al., 2015; Mimura, Komatsu, 2007; Fisher, Herman, Stephens, Vinogradov, 2016; Liu, Li, Xiao, He, et al; 2016; kirk, et al., 2015; Manger, Eikeland, & Asbjornsen, 2002; Ryan, Short, & Weed, 1986). Some scholars criticize the brain games and suggest that the cognitive improvements achieved by computer bran games have not proven to transfer to other contexts and domains and furthermore two dangers might be faced by computer-based brain gamers: withdrawal from physical activities and disengagement from social interactions (Ratner, Atkinson, 2015; Abikoff, 1985). Others have reported the effectiveness of cognitive training only in near transfer and to the immediate domain and have emphasized that it is domain-specific and that each domain requires a specific training program (Carpenter, Ledbetter, Moore, 2016; Bietenbeck, 2014; Wall, 2015; Talboom, West, Engler-Chiurazzi, Enders, & Crain, et al., 2014).

These controversies in part can be the result of issues arise from interpreting data in two or more un-similar situations (Noack, Lövdén, & Schmiedek, 2014) or the divergent methods used for interpreting the same set of data. Cognitive training improves the specific domain on which it is focused via direct and specific cognitive training not via general education (Ritchie, Bates, & Deary, 2015), therefore in order take the most advantage of the positive effects of students' raised cognitive skills, it is a must to embed specific and direct cognitive training into educational curriculum. Bietenbeck (2014) admits non-effectiveness and -even more- the negative effect of formal education in enhancement of higher cognitive skills such as reasoning skills. Walls (2015) explains that part of learning to think critically depends on the ability to judge whether an evolutionary response which has the availability heuristic or some other types of heuristics serves well or not. He also emphasizes the necessity of a curriculum in which critical thinking can be taught.

As a whole, restorative and compensatory cognitive training have shown to be beneficial for the impaired participants as well as for un-impaired individuals. The present research uses cognitive strategy training as well as personalized daily-life cognitive training activities to enhance executive functions and metacognition (knowing about knowing) in participants without a diagnosed cognitive impairment. The aim of the study is to help students and/or participants to take the responsibility of the practical application and transfer and of the cognitive strategies and adapt a desired and efficient way for practicing cognitive training activities by increasing their awareness about cognition, teaching them the most fruitful cognitive strategies and helping them to train their brain by specific goal-based exercises. It is supposed that if students are functionally trained, the real life application of the strategies would be facilitated.

2. Methodology

Study was of a quasi-experimental kind using an experimental and a waiting control group both selected via available sampling method. Participants were randomly assigned into experimental (n=61) and control groups (n=65). Both experimental and control groups took part in a pretest, post-test and a follow-up assessment, though an executive functioning training course was conducted after pretest and before post-test for the experimental group. The sample size was 126 participants, 57 male and 69 female. Seventeen participants were 18 years old, thirty-three were 17 and seventy-six 16 years old (Mean=10.04, SD= 0.72, in range of 15-18 years). All participants reported a normal way of life and not having a diagnosed crippling psychological situation. We performed the experiment in eight secondary high school classes (four for males and four for females) in autumn 2018. The committee of ethics of

Ministry of Science, Research and Technology in Shahid Beheshti University approved the study in 2016, Oct. 26 by the letter no. SBU.ICBS.95/1009. All participants signed an informed consent and were acknowledged their rights to know the research results and leave the study when they wish. They were also enlightened about the whole research process.

The experimental group received a twelve session intervention in executive functioning using Practical Cognitive Strategy Training (PCST) in Persian called Roshd [Rahborod-haye Shenakhti-ye Danesh-amoozan]. The data were analyzed by repeated measure ANOVA in SPSS 23. The study was an interventional one in which a 24-hour education conducted in twelve one-hour sessions, once a week. The administration sessions were designed once a week to provide enough time intervals for spacing and daily life adaptation and use and practice of strategies.

Three-stage assessment consisted of a three-section self-report questionnaire regarding personal information, well-being, strategy awareness and strategy use and four neuro-psychological tests. The self-report questionnaire consisted of : one section for six personal information (first name, family name, grade, name of school, gender), second section consisted of one open-ended question about health and mental issues, and the third section compromised of fourteen open-ended questions about cognitive awareness and use (two questions for working memory, two questions for cognitive inhibition, two questions for flexibility, three questions for meta-cognition: three questions for and two questions for problem solving). The neuropsychological tests consisted of n-back for assessing working memory (Jaeggi, Buschkuehl, Perrig, Meier, 2010; Kirchner, 1958), stroop test for assessing inhibitory control (Siegrist, 1997; Strauss, Allen, Jorgensen, Cramer, 2005), trail making test for assessing cognitive shifting (Reitan, 1958), and tower of Hanoi for assessing problem solving (Bishop, 2001; Gnys, Willis, 1991).

Training course consisted of a 24-hour education in executive functioning strategies designed to fulfill various individual needs based on the self-report questionnaire. In the first session, participants were introduced with executive functions and the main components thereof. They were also familiarized with the activities that were directly and indirectly relied on executive functioning and were informed about problems and disorders related to poor EF performance. In the following nine sessions, components of executive functioning were introduced one by one and the most salient strategies for each EF component were taught and practiced. Four sessions were devoted to teaching strategies to train and improve working memory and its components such as visu-spatial memory, verbal working memory and processing speed. Inhibitory control were taught and practiced in next two sessions and some strategies such as thought diet, anger control, meditation, selective concentration and graded overcome on disruptions were taught and practiced. Cognitive flexibility and planning and problem solving were also taught each for one session. Meta-cognition was integrated in the content of all sessions. Students were guided and helped to apply the strategies in real life situations according to their priorities and were guided to adapt the component cognitive training to their life conveniences. Students were asked to use the practiced sub skill in similar real life activities that were their personal or family concern and bring a report in the following session and ask their probable questions if necessary. The sub skills trained for executive functioning enhancement were visual and verbal working memory, chunking, grouping, mental imagery, mental calculations, checklists, goal setting, planning, memory strategies, inhibition, cognitive shifting, self-awareness, emotional-awareness, emotional control, attention control, self-management and self-monitoring. The activities chosen by each student was not time consuming and were to be continued until the end of the course on a regular basis for the purpose of consolidation and habit. The last two sessions were devoted to resolving individual problems in using strategies for their future goals on the basis of the issues they had faced during the course. The training course was designed carefully based on approved cognitive training strategies and adapted carefully to fit the students' real life situations and individual life styles to produce the optimum outcome. There was one month interval between pretest and post-test as well as between post-test and the follow-up test. The training course and the intervention training approved by professionals and corresponding literature to have face, content, criterion and construct validity. The self-report questionnaire was also tested for test retest reliability among 34 participants via two-tailed Pearson correlation (p= 0.01).

3. Findings

Neuro psychological tests are used to assess cognitive training improvement. The exercises used to improve cognitive neural bases (remediation) were introduced according to the rationale of this test. Preliminary investigation demonstrates demographic match between experiment and control groups regarding age and gender. Repeated measure ANOVA was conducted using SPSS 23 to investigate the effects of cognitive training on working memory, inhibition, cognitive flexibility and problem solving. The Box's Test of Equality indicates the significant equity in the obtained results of the experiment and control groups in working memory (F (2.15)=8.34, P < 0.05), cognitive inhibition (F (3.27)=20.15, P < 0.05), cognitive flexibility (F (3.97)=5.66, P < 0.05), problem solving (F (3.24)= 10.51, P < 0.05) Mauchly's Test of Sphericity also indicates that sphericity is not violated (P < 0.05) for all functions as well as the overall cognitive performance. The pre-test differences of control and experimental group obtained from neuro-psychological tests are presented in table below (Table 1).

Table1. The pre-test differences of control and experimental group obtained from neuro-psychological tests

Dependent Variables	Control Group		Experimental Group	
	Mean	Std.	Mean	Std.
Working Memory	4.42	2.81	4.41	2.98
Inhibitory Control	1.73	2.78	1.45	2.63
Cognitive Flexibility	11.27	4.36	12.27	5.25
Problem Solving	4.80	2.90	6.29	3.42

As indicated in table 1, there is not a significant difference between the means of the control and experimental groups in neuro-psychological tests in pre-test assessment. The obtained scores of the pre-test assessment are compared with post-test assessment and follow up assessment using repeated measure ANOVA in table below (Table 2).

Table2. The pre-test & post-test difference and pre-test & follow-up test significance in Repeated Measure ANOVA in neuro-psychological tests

Dependent Variables	Pre-Test & Post-Test		Pre-Test & Follow-up	
	F	sig	F	sig
Working Memory	586.01	0.00	50449	0.00
Inhibitory Control	605.04	0.00	538.33	0.00
Cognitive Flexibility	1129.72	0.00	1549.16	0.00
Problem Solving	1812.02	0.00	1647.44	0.00
Overall Results	4001.02	0.00	3619.83	0.00

Results demonstrate that there is a significant difference between experimental and control group after PCST in post and follow up tests. In the second part of the analysis we compare the EF scores which were calculated by the points given to the answers students provided for self-report questionnaire. The questionnaire was designed to assess cognitive strategies used and learned by participants (compensatory cognitive training). The questionnaire asked students to report the strategies they used for specific real life indices they encountered and could be regarded a result of EF capabilities. Planning and problem solving were marks as a single score. Pretest results were regarded as the intervention baseline for intervention. Repeated measure ANOVA was conducted using SPSS 23 to investigate the effects of cognitive training in working memory, inhibition, cognitive flexibility, meta-cognition, planning, problem solving and overall cognitive performance in executive functions. The Box's Test of Equality indicates the significant equity in the obtained results of the experiment and control groups in working memory (F (2.88)=17.76, P <

0.01), cognitive inhibition ($F (3.27)=20.15$, $P < 0.01$), cognitive flexibility ($F (7.98)=49.23$, $P < 0.01$), meta-cognition ($F (1.61)=9.93$, $P < 0.5$), planning ($F (5.52)=34.01$, $P < 0.01$), problem solving ($F (4.44)= 27.39$, $P < 0.01$), and overall cognitive performance ($F (2.46)=15.18$, $P < 0.05$). Mauchly's Test of Sphericity also indicates that sphericity is not violated ($P < 0.05$) for all functions as well as the overall cognitive performance. The pre-test differences of control and experimental group obtained from self-report questionnaire are presented in table below (Table 3).

Table3. The pre-test differences of control and experimental group obtained from self-report questionnaire

Dependent Variables	Control Group		Experimental Group	
	Mean	Std.	Mean	Std.
Working Memory	4.39	2.27	4.86	1.83
Inhibitory Control	4.34	2.47	3.44	2.37
Cognitive Flexibility	1.34	1.12	1.01	1.52
Problem Solving	1.27	2.69	1.32	2.66
Meta-Cognition	4.80	2.90	6.29	3.42
General Executive Functioning	16.14	4.96	16.92	5.39

Table 3 shows that there is not a significant difference between the means of the control and experimental group in pre-test assessment. The obtained scores of the pre-test self-report questionnaire are compared with post-test assessment and follow up assessment using repeated measure ANOVA in table below (Table 4).

Table4. The pre-test & post-test difference and pre-test & follow-up test significance in Repeated Measure ANOVA in self-report questionnaire

Dependent Variables	Pre-Test & Post-Test		Pre-Test & Follow-up	
	F	sig	F	sig.
Working Memory	2971.14	0.00	2355.12	0.00
Inhibitory Control	1364.29	0.00	1178.33	0.00
Cognitive Flexibility	4439.42	0.00	4326.05	0.00
Problem Solving	2303.17	0.00	2424.54	0.00
Meta-Cognition	3459.31	0.00	3420.77	0.00
General Executive Functioning	3867.65	0.00	3697.74	0.00

The results indicate that after cognitive training, there were a significant difference between the scores of the experimental and control groups. It shows that the experimental group had improved in the application of strategies in daily life activities.

4. Discussion

The results of the present paper represented the efficacy of cognitive training on ef performance and meta-cognition of adolescents. This finding is in line with the prior literature (Klein, et al., 2017; Galetto, Sacco, 2017). These findings were similar in neuro-cognitive tests and self-reports questionnaire. The neuro-cognitive test were applied to assess underlie EF capacities to provide the base for remediation cognitive training. Activities to practice speed processing, shifting attention, inhibit impulsive reactions and mental investigation were applied to enhance this dimension and proved to be effective. It approves near transfer of cognitive training.

The second part of the study asked students to name the strategies they use while there was need for inhibition, cognitive control, shift attention, and solve problems. They were also asked to report what they know about their cognitive performance (strengths and weaknesses). The scores were analyzed individually and as whole EF score. Then they were encouraged to practice and apply more brain friendly strategies to bring then better results. At the end of the course, there was a significant improvement in the scores of the experimental group compared with the control group. This part represented the compensatory cognitive training and the results were in line with the previous research. It also provided more evidence for moderate and far transfer of cognitive training (Cicerone, et al, 2011; Hegde, 2017; Ahn, Hwang, 2017).

The main proposed problem about cognitive training is the transferability of the training materials. While the brain training games and programs have provided a glaring evidence for the improvement of performance of the trained function, the most important criticism about brain training and cognitive training programs has been its lack or little power of transfer to other activities and the functions and activities that rely partially on the trained function. The main concern of the present study was to focus on real life, personalized cognitive training to fill the transferability gap. Training for transfer differs from training for acquisition and needs more time (Cormier, Haghman, 1987) and some strategies should be incorporate in the training programs to guarantee the results to a possible extent. When talked about cognitive training (remediation or compensatory), the direction of attention goes toward games and videos straightforward. Although the significance and importance of these activities should not be undermined, the applicability and practicality of the activities and the possibility of their engagement and amalgamation in real life situations should be of a major interest because the functions should be interwoven in real life situations if they are going to help overall well-being and improved performance. In individualized interventions, the therapist can help participant to develop goal-directed strategies but in group interventions this responsibility lies on participants so one of the goals of training should be teaching real life goal-directed strategy adaptation (Lampit, Hallock, Valenzuela, 2014).

The longitudinal effect of the cognitive training in a one-month follow-up assessment can give rise to the plausibility and necessity of the involvement and induction of executive functioning strategies -as a brain friendly educational program- into the educational curriculum and psychological counselling sessions. Any brain training program can lead to some change in synoptic relations of the brain neurons. The working memory development and working memory enhancement have similar mechanism –activity on neurons that leads to generation and increase of the synaptic connectivity and white matter volume (Klingberg, 2016) so we should not consider cognitive training programs as a way to help the disabled but as a way to enhance the healthy individuals brain capabilities. More research is needed to specify which exercises have more significant and accurate results. There is no conflict of interest in this research. We appreciate the effort and support of those educators and participants who helped us for the administration of this research.

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