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The Effect of Computerized Cognitive Training Program on Working Memory, Cognitive Flexibility, and Inhibitory control as Executive Functions in managers of National Iranian Oil Company

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This study was undertaken to examine the effect of computerized cognitive training program on working memory, cognitive flexibility, and Inhibitory control as executive functions in managers of the National Iranian Oil Company (NIOC). The current study is experimental research based upon a pretest-posttest design with a control group. The statistical population of the study consisted of all middle managers of the NIOC. Through a public call, managers who were willing to participate in computerized cognitive training program were invited to declare their interest. At this stage, 300 managers expressed their willingness to participate. From this group, 30 individuals who fulfilled the inclusion criteria were selected using a simple random sampling method. Thereafter, using random assignment, 15 participants were assigned to the experimental group and 15 to the control group. Prior to the intervention, participants were evaluated using appropriate instruments, including the N-Back Task, Wisconsin Card Sorting Test, and Go/No Go Test. Following the evaluation, the participants in the experimental group underwent 24 sessions of computerized cognitive training program. Each session lasted 24 minutes. The participants in the control group did not receive any intervention. The participants were re-evaluated immediately after completing the intervention sessions. MANCOVA and separate ANCOVAs analyses revealed that computerized cognitive training program can lead to improvements in working memory, cognitive flexibility, and Inhibitory control ($p < .05$). Based on the research results, computerized cognitive training program can be employed to enhance executive functions for managers.

Keywords: working memory, cognitive flexibility, Inhibitory control, computerized cognitive training program.

Strategic research indicates that the fundamental decisions of senior-level managers in strategic choice are critical. Such decisions carry significant implications for organizational success. Strategic decisions in the context of performance threats represent complex decision-making conditions for managers, necessitating underlying cognitive processes (Treffers et al., 2020). Previous research has suggested that executive functions (EFs) play a key role in job performance as they enable successful professionals to exhibit better social, cognitive, and executive performance (Willoughby & Blair, 2016).

EFs refer to a subset of high-level cognitive abilities that maintain adaptive goal-directed thought and behavior. They are prerequisites for sustained focus, regulation of attentional resources and automatic responses, as well as rapid, flexible adaptation to changing environmental demands. These components support more complex cognitive functions—such as reasoning, planning, decision-making, creativity, and problem-solving—which are fundamental skills for professional success and optimal job performance (Balconi et al., 2020).

There are three core EFs: I) Inhibitory control (the ability to control one's behavior, thoughts, or emotions to override impulsive reactions); II) Working Memory (the ability to temporarily store and manipulate auditory or visuospatial information); and III) Cognitive Flexibility (the ability to shift strategy or approach when problem-solving or completing a task) (Baddeley, 2012; Diamond, 2013; Logue & Gould, 2013; Pahor et al., 2018; Hyman, 2017).

It is now confirmed that EFs may support social and self-regulatory skills, which play an essential role in the successful management of social dynamics, interpersonal relationships, and adaptive stress management (Cacioppo & Cacioppo, 2020). Based on such assumptions, it can be argued that EFs enhance skills such as adaptive stress management, empathy, interpersonal and communication effectiveness, and leadership. Thus, they merit specific attention and have implications for human resource development programs as well as assessment.

Deficits in EFs are consistently linked to impaired cognitive functioning. Abnormal changes in EFs are considered to be related to the symptoms of many psychiatric disorders (Snyder, 2013; de Vries et al., 2014; Degutis et al., 2015). For instance, patients suffering from depression exhibit increased attention to, as along with enhanced memory for, negative emotional content

(Wiegand et al., 2019). Further, with advancing age, changes occur in the prefrontal cortex and medial temporal lobe, including the hippocampus and cerebellum (Gorelick et al., 2016). These changes are associated with Alzheimer’s disease and dementia, together with impairment in cognitive processes such as short- and long-term memory, processing speed, and EFs. As such, cognitive functions—including attention, memory, and analytical ability—decline functionally with age (Al-Thaqib et al., 2018).

Nevertheless, EFs are not static and can be enhanced through various interventions (Lu et al., 2021; Ahmadi Farsani et al., 2021). There is also evidence for effective training of EFs across healthy adult populations (Ballesteros et al., 2014; Nouchi et al., 2013).

Currently, cognitive modification can be delivered via two generally accepted approaches: computerized cognitive modification and paper-and-pencil tasks administered by a trained professional. Further, computerized cognitive modification can be classified into professional-guided computerized cognitive training and software-based cognitive training. Software-based training programs allow individuals to engage in cognitive exercises at home with minimal contact with a professional (McDonnell et al., 2017). With the advances in technology, software-based cognitive modification is becoming increasingly popular thanks to its accessibility, ease of use, as well as minimal interference with daily life activities (Peek, 2015). These cognitive software programs bring cognitive modification into individuals' personal homes, and their usage in the general population seems promising, offering an engaging way to strengthen and maintain normal brain function. In addition, a wide range of exercises are utilized in cognitive software programs (McDonnell et al., 2017).

A meta-analysis by Grynszpan et al. (2011) highlighted the benefits associated with computerized cognitive modification. Computerized graphics allow for a more dynamic test compared to paper versions and create a "multi-sensory presentation" of the training exercises. Immediate feedback on performance is also an advantage, allowing the individual to receive results immediately once a training session is completed. Given the lack of contact with a professional during computerized cognitive training, objective and unbiased results can be obtained. The exciting and game-like exercises employed by computerized cognitive modification programs are more entertaining and motivating for users than other cognitive training programs. Some of the largest randomized controlled trials (RCTs) on computerized cognitive training have reported evidence for cognitive enhancement as well as its transfer to everyday cognitive function (Rebok et al., 2014; Wolinsky et al., 2013; Zelinski et al., 2011). A recent meta-analysis of cognitive training and a pilot study indicated the benefits of brain training on cognitive function, especially in terms of transfer to untrained tasks (Mewborn et al., 2017). The latter study also reported short-term functional and long-term structural changes associated with overall cognitive gains (Lampit et al., 2015a; Lampit et al., 2015b).

The underlying premise of cognitive training is that, due to neuroplasticity, at least some cognitive mechanisms can be improved through repeated exposure to cognitive exercises (Karbach & Schubert, 2013; Sala et al., 2019). The evidence for the effectiveness of brain training games is similar to that of other cognitive training programs: there is evidence for near transfer to similar trained tasks as well as limited evidence for far transfer to dissimilar tasks (Parong & Mayer, 2020). Nevertheless, the beneficial effects of EF training have been found to depend on the amount of training, with a greater number of training sessions yielding larger transfer effects than shorter series of sessions (Barker et al., 2021). Training transfer effects are maximized when different cognitive skills are integrated (Taatgen, 2013); high levels of engagement and motivation are maintained (Maraver et al., 2016); and individuals are sufficiently exposed to the task (Zhao et al., 2020).

A meta-analysis by Brito et al. (2017) on 20 studies published over 20 years revealed that computer games have a positive influence on cognitive functions such as response speed, attention, and memory, and can be utilized as a beneficial intervention to improve mental capabilities. Further, brain scans have also indicated that certain activities—such as meditation, visiting complex areas, learning magic tricks or a musical instrument, and playing video games—may alter brain structure and function, even in adulthood (Rabipour, 2019).

Theories of expert performance improvement state that the enhancement of expert skill takes place when learners practice the skill in question at high levels of challenge, which requires continuously elevating the challenge levels as individuals' performance improves (Wells et al., 2021). High success has been reported for cognitive games that adhere to design principles through providing repeated and focused practice on a specific executive function skill in multiple contexts with increasing challenge levels as well as feedback (Anguera et al., 2013; Parong et al., 2017).

EFs are the primary target of brain training (Pahor, et al., 2018). Specifically, brain training games add gamified elements to cognitive tasks in an attempt to ameliorate certain cognitive elements. The gamification of cognitive training often involves aesthetic elements—such as the use of more art or music, mechanisms such as a reward system (often based on levels and scores), and a designed storyline to entertain users—which is more motivating for individuals than other cognitive training programs (Anguera & Gazzaley, 2015; Kapp, 2012).

A recent systematic review of brain training interventions or "brain games" found extensive evidence for enhanced performance on trained tasks (Simons et al., 2016). Anderson and Bavelier (2011) have suggested that playing video games places high demands on specific cognitive components, which should facilitate the improvement of these components. Numerous studies that have utilized brain training games as an intervention have reported boosted performance on cognitive tasks such as speed, accuracy, visual-motor coordination, attention, memory, working memory, and overall cognitive function (McDougall & House, 2012; Toril et al., 2014; Janssen et al., 2014; Leckie et al., 2012). Evidently, regular engagement is a crucial factor in any type of training (Robb, 2021). Intervention studies suggest that the association between video game playing and enhanced cognitive skill is not merely correlational, but causal. Studies demonstrate that the effects of video games on individuals' skills and abilities persist for a significant period after playing them (Novick et al., 2020).

Unlike standard laboratory training tasks or most brain trainers, video games are rewarding. Indeed, the neural circuits present in primary reinforcers such as food and water are also activated by video games. Such reinforcement is significant for learning and in its own right, as the neural systems involved in reward encoding have been found to promote neuroplasticity (Novick et al., 2020). This reinforcement also motivates individuals to continue playing, with the time individuals spend on a task being one of the predictors of learning (Przybylski et al., 2010). Further, video games are physiologically arousing. The well-known Yerkes-Dodson law states that learning has an inverted U-shaped relationship with arousal (Yerkes & Dodson, 1908). The greatest amount of learning takes place at a medium level of arousal. The study by Tobias et al. (2014) also noted that digital game-based learning can ameliorate the level of cognitive abilities such as attention skills, working memory capacity for storing and manipulating spatial images, decision speed, and task execution.

In this regard, given the critical role of cognitive functions in the professional performance of organizational managers (especially in areas like decision-making, planning, and strategy formulation), as well as the changes in these functions across the lifespan and owing to various events, and since, to the best of our knowledge, only limited research has been undertaken on this topic in Iran, the present study intends to determine the effect of computerized cognitive training program on a group of managers to boost working memory, cognitive flexibility, and inhibitory control as EFs affecting their individual and organizational professional performance.

Method

The present study applied an experimental method using a pretest–posttest design with a control group. The statistical population of the study consisted of all middle managers of the National Iranian Oil Company (NIOC) along the years 2025–2026. Through a public call, managers who were willing to participate in computerized cognitive training program were invited to declare their interest. At this stage, 300 managers expressed their willingness to participate. From this group, 30 individuals (15 women and 15 men) who fulfilled the inclusion criteria and were accessible for follow-up were selected using a simple random sampling method.

The inclusion criteria were as follows: willingness and informed consent to participate in the research, having a minimum of three years of managerial experience, and not receiving any intervention or training other than the intervention provided in the present study. Thereafter, using random assignment, 15 participants were assigned to the experimental group and 15 to the control group. The exclusion criteria included withdrawal of consent to continue participation, concurrent participation in similar training programs, as well as failure to regularly complete the tasks of the computerized cognitive training program.

Prior to implementation of any intervention, ethical approval related to the present research was obtained (Ethics Code: IR.SCU.REC.1403.120). For informing participants, a session was held in which explanations were provided considering the study and its objectives. The participants were informed that the tests would be completed anonymously using coded identifiers and that their entire information would remain confidential. Preintervention assessment (pre-test) was conducted for both groups. In the second phase, the participants in the experimental group completed the computerized cognitive training program, which involved 24 sessions of 24 minutes each over a period of eight weeks (three sessions per week). Along this phase, the control group did not receive any training or intervention. At the end of the third phase, both the experimental and control groups underwent post-intervention assessment (post-test). Following completion of the study, the control group was also provided with the computerized cognitive training program free of charge.

Instruments

N-Back Task

The N-Back task, first introduced by Kirchner in 1958, was developed to ascertain working memory. It concurrently measures the capacity for holding cognitive information and the ability to manipulate information within working memory. Regarding the general procedure, a sequence of stimuli (usually visual) is presented step-by-step to the participant, who must check whether the currently presented stimulus matches the stimulus that appeared n steps earlier. The experiment is performed with different values of n, and as n increases, so does the task difficulty. For instance, in the 1-back task (n=1), the last presented stimulus is compared with the previous one, and in the 3-back task (n=3), the last presented stimulus will be compared with the stimulus presented three steps prior. In this test, the number of correct responses is regarded as the main index for measuring working memory. There are different versions of this test. In the current research, the 1-back task from the Iranian software version of this test, designed by Khodadadi et al.

(2014), has been employed. The validity coefficients of this test have been reported to range from .54 to .84, and its reliability, ascertained using the test–retest method, has been reported to range from .87 to .90 (Kane et al., 2007; Hepdarcan & Can, 2025). Since this test is non-verbal and not culture-dependent, the evidence of its validity and reliability from international studies was considered sufficient.

Wisconsin Card Sorting Test (WCST)

This test was developed by Grant and Berg (1948) and is widely applied as a tool to appraise EFs, particularly flexibility. Successful performance on this task necessitates strategic planning, abstract ability, mental flexibility, goal-directed behavior, organized search, as well as control of impulsive responses. The test has been extensively employed to evaluate frontal lobe function. It consists of 64 cards that differ based on color, shape, and number. The participant's task is to sequentially place other cards beneath four main cards (which are, in order, 1 red triangle, 2 green stars, 3 yellow crosses, and 4 blue circles) according to a sorting principle they must deduce from the pattern of the examiner's feedback considering their own card placements. The output of this test includes the number of correct responses, number of categories completed, and perseverative errors. In the present study, the Perseverative Error score, which is the main index for measuring cognitive flexibility, was employed to ascertain this executive function. A perseverative error is observed when the participant continues to sort according to the previous rule in spite of the categorization rule having changed, or sorts the cards based on an incorrect hypothesis and persists in their wrong answer despite receiving "incorrect" feedback (Mueller & Piper, 2014). In the study by

Spreen and Strauss (1998), the reliability of this test was reported as .83, based on the inter-rater agreement coefficient. There are multiple versions of the Wisconsin Card Sorting Test. In the current research, the Iranian computerized version of this test, developed by Khodadadi et al. (2014), was employed. This version is employed to ascertain cognitive flexibility and assess frontal lobe impairments. The discriminant validity of this test is reported to be high in individuals with high and low anxiety, with the Cronbach's alpha coefficients for the number of completed categories and the number of perseverative errors being reported as .73 and .74, respectively. Since this test is non-verbal and not culture-dependent, the reported validity and reliability in foreign studies were deemed sufficient.

Go/No-Go Task

In the Go/No-Go task (Casey et al., 1997), in one condition (the Go phase, execute, or movement), the individual is asked to respond to a stimulus as quickly as possible with a compatible response. In the other condition (the No-Go phase, inhibit, or movement stop), a second stimulus is presented following the first stimulus, whereby the individual needs to refrain from responding upon the appearance of the second stimulus. The two types of Go and No-Go situations are randomly presented within a single task. The individual's ability to inhibit their response in the second situation is an index of their inhibitory control. This test has different versions. In the current research, the Iranian software version designed by Khodadadi et al. (2014) was employed. In this test, the number of correct and incorrect responses in each situation as well as the mean response time are recorded by the software. The number of false alarms to the No-Go stimulus, or the error of commission, is considered the main index for measuring inhibitory control. Since this test is non-verbal, not culture-dependent, and has a neurobiological basis, citations from foreign studies on its validity and reliability are applicable. Response errors and reaction time in the Go/No-Go task are correlated with other response inhibitory control tasks, reflecting the construct validity of this task in measuring behavioral inhibitory control (Hachenberger et al., 2025). Test–retest reliability of the Go/No-Go task has also been reported to exceed .80 (Casey et al., 1997).

Computerized cognitive training program (Maghzineh)

In the present study, the "Maghzineh Attention and Concentration Program" (Ekhtiari et al., 2016) was applied for cognitive training. This program includes 24 sessions, each lasting 24 minutes (comprising 16 games of 90 seconds each). Overall, task difficulty is progressively augmented based on individual performance. The Maghzineh Attention package was designed and developed based upon academic research and is made available to the public by Pars Cognitive Technologies Company. Each game is designed and developed to target one or more specific attention parameters, such as sustained attention or selective attention. Further, the games may also influence other cognitive parameters such as short-term memory or response time (see Table 1). The games are accessible via a web browser or an Android application. In this study, 12 tasks or games from the attention package were utilized as the training program.

Table 1
Targeted Cognitive Functions of Games in the Maghzineh Program

No.	Game Title	Targeted Cognitive Functions
1	Error-Free Performance	Selective Attention, Sustained Attention, Attentional Shifting, Alertness
2	Choir Group	Sustained Attention, Attentional Shifting, Working Memory, Alertness
3	Photo Gallery	Sustained Attention, Attentional Shifting, Working Memory, Alertness
4	Control Officer	Focused Attention, Sustained Attention, Working Memory, Processing Speed, Alertness
5	Rain Clouds	Divided Attention, Working Memory, Processing Speed
6	Flavor finder	Selective Attention, Attentional Shifting, Processing Speed
7	Honey Memory	Sustained Attention, Working Memory, Alertness
8	Lost at Sea	Selective Attention, Response Inhibitory control Processing Speed
9	Highway	Selective Attention, Response Inhibitory control Processing Speed
10	Word Memory	Sustained Attention, Attentional Shifting, Working Memory
11	Puzzle	Selective Attention, Attentional Shifting
12	Visual Memory	Sustained Attention, Attentional Shifting, Working Memory

Results

The mean (and SD) age of participants in the experimental group was 43.87 (3.62), while the control group had a mean (and SD) age of 46.21 (4.32). Group-specific means and standard deviations for the studied variables are listed in Table 2.

Table 2
Mean, Standard Deviation, Minimum and Maximum Scores of the Variables

Variable	Group	Stage	Mean	SD	Min	Max
Working Memory	Control	Pre-test	102.87	4.98	95	113
		Post-test	103.13	4.66	97	112
	Experimental	Pre-test	103.40	5.25	94	112
		Post-test	110.07	5.62	98	117
Cognitive Flexibility	Control	Pre-test	3.67	2.66	0	9
		Post-test	3.93	1.75	1	7
	Experimental	Pre-test	3.60	2.50	0	9
		Post-test	2.20	1.66	0	5
Inhibitory control	Control	Pre-test	2.67	1.72	0	6
		Post-test	2.93	1.16	1	5
	Experimental	Pre-test	2.53	1.73	0	6
		Post-test	1.07	.88	0	3

Both multivariate and univariate analyses of covariance (MANCOVA and ANCOVA) were employed. Prior to conducting these analyses, the assumptions required for MANCOVA—namely normality, homogeneity of variances, homogeneity of variance–covariance matrices, and homogeneity of regression slopes—were appraised. Shapiro–Wilk tests at pre-test and post-test revealed that all variables fulfilled the normality assumption except Inhibitory control in the experimental group at post-test. Since skewness and kurtosis values for the dataset fell between −3.29 and +3.29 (appropriate for small samples), the usage of parametric tests was considered acceptable. Levene's test was employed to assess homogeneity of variances; its results for all post-test variables yielded nonsignificant F values at the alpha level of .05, supporting homogeneity of variances. Box's M test was applied to appraise homogeneity of the variance–covariance matrices at post-test; these results are reported in Table 3.

Table 3
Results of the Homogeneity of Variance-Covariance Matrices using Box's M test

	Post-test
Box's M	7.211
F	1.061
Degree of Freedom 1	6
Degree of Freedom 1	5680.302
Significance Level	.384

Table 3 indicated no significant differences ($p>.05$) between the correlation matrices of the dependent variables across the study groups, thereby confirming the assumption of equality of the variance–covariance matrices.

As outlined in Table 4, the interaction between group and pre-test scores on post-test outcomes was not statistically significant for any variable. Thus, the assumption of homogeneity of regression slopes for the post-test was satisfied.

Table 4
Investigation of the Assumption of Homogeneity of the Regression slopes

Stage	Variable	Source	Sum of squares	Degree of Freedom	Mean square	F	Sig.
Post-Test	Working Memory	Pre-Test and Group	11.133	2	5.566	1.172	.328
	Cognitive Flexibility	Pre-Test and Group	.400	2	.200	.253	.779
	Inhibitory control	Pre-Test and Group	1.115	2	.557	.743	.487

Since the stated assumptions were met, both multivariate and univariate covariance analyses were undertaken to analyze the data.

Wilks' Lambda for the post-test revealed a significant multivariate effect, signifying differences among the groups on at least one dependent variable. Further, the effect size from the post-test suggests that the independent variable accounted for 87% of the variance in the continuous outcomes ($p < .05$; $F = 50.673$; Eta = .87).

Table 5
Results of Multivariate Analysis of Covariance (MANCOVA)

Stage	Index	Value	F	Hypoth esis df	Error df	Sig.	Partial Eta	Observe d Power
Post-Test	Wilks' Lambda	.131	50.673	3	23	.000	.869	1

The MANCOVA thus demonstrated a significant overall difference between the control and experimental groups on at least one dependent measure, but did not specify which measure(s) differed. Accordingly, follow-up univariate ANCOVAs were carried out, with its results summarized in Table 6.

Table 6 indicates that the F statistic for working memory at post-test was 65.909, reflecting a significant between-group difference in working memory during the post-test phase. The F statistic for cognitive flexibility at post-test was 30.076, indicating a significant difference between groups on cognitive flexibility. Finally, the F statistic for inhibitory control at post-test was 33.440, signaling a significant between-group difference in inhibitory control at post-test.

Table 6
Results of ANCOVA Analysis Comparison of differences between Experimental and Control Groups in Working Memory, Cognitive Flexibility, and Inhibitory control

Stage	Variable	Source	Sum of squares	df	Mean square	F	Sig.	Partial Eta Squared	Observed Power
Post-Test	Working Memory	Group	317.377	1	317.377	65.909	.000	.725	1
	Cognitive Flexibility	Group	22.356	1	22.356	30.076	.000	.546	1
	Inhibitory control	Group	24.571	1	24.571	33.440	.000	.572	1

Discussion

The findings of the present study indicated that the computerized cognitive training program significantly boosts working memory in managers. Specifically, the results revealed a statistically significant difference between the mean scores of working memory at the pre-test and post-test phases. These findings are in accordance with prior research, including studies by Corbett et al. (2024), Fang et al. (2024), and Zhang et al. (2025).

Corbett et al. (2024) reported that managers who participated in an eight-week working memory training program presented a significant improvement in information retention and multitasking performance along managerial simulations. Similarly, Fang et al. (2024) noted that eight weeks of computerized working memory exercises resulted in notable neurofunctional improvements. Further, a meta-analysis conducted by Zhang et al. (2025) revealed that adaptive working memory training in employed adults yields moderate to large effects, with evidence of transfer to real-world occupational settings.

The causal mechanisms underlying the effectiveness of computerized working memory training can be explained as follows:

(1) Strengthening neurophysiological networks: Neuroscientific research has demonstrated that computerized working memory training (e.g., N-back tasks) activates, reinforces, and reorganizes frontoparietal networks, which play a key role in the maintenance, updating, and manipulation of information in the working memory (Lee et al., 2024). According to neuroimaging studies, repeated training enhances

neural efficiency in these regions—either by lowering neural load for equivalent performance or by enhancing network efficiency through increased functional connectivity—leading to observable behavioral improvements on memory tasks. This mechanism explains the augmented performance observed in managerial tasks requiring information retention and processing following training (Zhang et al., 2024). Evidence from controlled experimental studies further indicates that improvements in working memory performance after computerized training are accompanied by diminished activation in frontoparietal networks, reflecting heightened neural efficiency (Bomyea et al., 2025). Such findings support the notion that behavioral gains in working memory are driven by functional changes in relevant brain networks.

(2) Increased processing capacity and efficiency: Targeted training may operate through two pathways: expanding maximum storage capacity or boosting processing efficiency within the existing capacity. For managers, gains in efficiency—such as faster responses and lowered errors in multi-item maintenance—are of greater practical relevance, as they contribute to diminished decision-making time and error rates (Syed et al., 2024).

(3) Adaptive training and enhanced cognitive challenge: A key strength of computerized cognitive training programs lies in their ability to dynamically adjust task difficulty based upon individual performance, ensuring that participants remain within an optimal learning zone. This adaptability prevents maladaptive habituation and superficial learning while promoting neural pathways that support enhanced processing capacity. According to empirical evidence, adaptive programs exert stronger effects

on working memory outcomes compared to fixed-difficulty interventions (Zhang et al., 2025; Rodas et al. 2024)

(4) Repetition and immediate feedback: Repeated practice combined with rapid feedback facilitates consolidation of working memory skills as well as their application in real occupational contexts. Immediate feedback allows individuals to identify and correct errors, resulting in the formation of more efficient cognitive strategies.

(5) Transfer to occupational performance (near and far transfer): One longstanding challenge in cognitive training research concerns indicating transfer from training tasks to real-world job performance. Workplace studies suggest that structured remote or computerized training programs can ameliorate not only test performance but also indicators of occupational efficiency and job satisfaction (Shibaoka et al., 2024).

The results of the present study further indicated that the computerized cognitive training program had a significant influence on enhancing cognitive flexibility in managers. A significant difference was observed between the mean scores of cognitive flexibility at the pre-test and post-test stages. These findings are supported by previous research conducted by Lee et al. (2024), Uhlig et al. (2023), Tagliente et al. (2025), and Holzer et al. (2024).

According to Lee et al. (2024), task-switching training and adaptive exercises significantly improve managers' cognitive flexibility. Similarly, the meta-analysis by Uhlig et al. (2023) indicated that multi-component training programs facilitate transfer to real occupational environments, enabling managers to adopt alternative decisions more rapidly. Tagliente et al. (2025)

further noted that these effects extend beyond laboratory settings to simulated work environments. Further, Holzer et al. (2024) reported that cognitive flexibility training generates beneficial behavioral and clinical outcomes, suggesting that flexibility-related mechanisms remain modifiable and potentially generalizable to healthy working populations, including managers.

The causal mechanisms underlying the effectiveness of computerized training on cognitive flexibility include:

(1) Strengthening executive neural networks: Multi-task computerized programs that integrate task-switching, rapid alternation between rules, content updating, attentional control, and inhibitory control promote interactions between executive components—namely prefrontal regions responsible for strategic regulation and parietal-cortical networks involved in information representation. Repeated practice in set-shifting and updating tasks strengthens frontocortical and lateral networks that form the behavioral foundation of cognitive flexibility. This would facilitate faster rule switching, improve perspective shifting, enhance processing of variable information, as well as contribute to more efficient updating of the active mental content (Lee et al., 2024).

(2) Role of adaptive and multi-modal training: Modern programs dynamically tailor task difficulty to individual performance, maintaining participants within an optimal learning zone as well as enabling effective consolidation of flexibility skills. Multi-component interventions that incorporate task-switching, variable problem-solving, and attentional control exercises induce stronger effects on cognitive flexibility than single-task approaches. This is possibly because cognitive

flexibility is an inter-task process requiring coordination across multiple EFs. Based on recent reviews, adaptive, personalized multi-component interventions generate the most robust improvements in cognitive flexibility (Lee et al., 2024).

The findings of the present study also indicate that the computerized cognitive training program significantly improves inhibitory control in managers. A statistically significant difference was observed between the mean inhibitory control scores at the pre-test and post-test phases. These results are in accordance with previous studies conducted by Li et al. (2022) and Rodas et al. (2024).

Li et al. (2022) found that Go/No-Go task training reduced impulsive responses among managers in decision-making simulations. Further, the meta-analysis by Rodas et al. (2024) noted that inhibitory training yields a moderate effect size in adults, with effects remaining stable for up to six months.

The causal mechanisms underlying the effectiveness of computerized inhibitory control training include:

(1) Strengthening prefrontal circuits and inhibitory pathways: Targeted computerized tasks (e.g., Go/No-Go paradigms) repeatedly activate prefrontal regions along with inhibitory networks responsible for impulse control. Repeated activation promotes synaptic strengthening and network efficiency, leading to faster and more accurate response inhibitory control. According to empirical evidence, response-inhibitory control training results in both behavioral improvements and neurofunctional changes (Li et al., 2022).

(2) Adaptive difficulty, optimal learning zone, and training challenge: Adaptive programs that adjust difficulty according to individual performance keep participants within an optimal

learning zone, boosting training effectiveness and promoting transfer not only to trained tasks (near transfer) but also to structurally similar tasks. Evidence suggests that difficulty modulation is a prerequisite for achieving stable behavioral change (Zhang et al., 2025).

(3) Immediate feedback: Rapid feedback enables individuals to correct errors and consolidate accurate response patterns in memory, leading to sustained improvements in inhibitory control.

One limitation of the present study was that the statistical population consisted exclusively of managers from NIOC; thus, generalization of the findings to other populations should be undertaken with caution.

Further, conducting a follow-up phase was not feasible, Due to logistical constraints within the NIOC. Consequently, it was not possible to evaluate the long-term efficacy and sustainability of the computerized cognitive training program.

Given these limitations, it is recommended that similar studies be undertaken across governmental organizations as well as other private sector institutions to enhance the generalizability of the findings. Further, to more rigorously examine the durability of computerized cognitive training effects on executive functions, it is suggested that future research incorporate follow-up assessments at appropriate intervals post-intervention.

Based on the results of the present study, it is recommended that senior managers and officials of NIOC allocate sufficient time as well as financial resources for the cognitive training of managers and employees in order to enhance these executive cognitive functions.

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