Original Research Article

EFFECT OF WORKING MEMORY TRAINING ON FLUID INTELLIGENCE

ABSTRACT

This true experimental research anchored on the Cattell-Horn-Caroll (CHC) theory utilized Randomized Two-Groups Design to examine the effect of working memory training on the fluid intelligence of high school students. Thirty-five students from a selected public high school in Negros Occidental were randomly selected and assigned using multi-stage sampling. In measuring the fluid intelligence, the Culture Fair Intelligence Test was administered as pretest instrument in establishing baseline data. Once baseline data have been established, the experimental group commenced with a working memory training called *n*-back task for four weeks with three sessions per week. After the intervention, both groups were retested using the same test, the CFIT. Data collected were collated and analyzed. A paired t-test on the experimental group revealed a significant gain between pretest and posttest results of the participants. Meanwhile, a paired t-test on the control group comparing their scores in the pretest and posttest do not yield a significant difference indicating a gain in fluid intelligence among the participants in the experimental group is brought about by the working memory training. In addition, considering the posttest results of the experimental and control group using an independent sample t-test a statistically significant difference in the scores can be found. Moreover, a relatively high effect size suggests an overall high effect of the intervention on the fluid intelligence of the participants. Finally, profile variables such as sex, academic performance and household monthly income are not considered to be predictors of gains in working memory training.

Keywords: working memory training, *n*-back task, fluid intelligence, CFIT, randomized two-groups design

INTRODUCTION

Historically, human intelligence has been the center of debates and discussions even from the time of the great philosophers such as Plato and Aristotle (Kaufman, 2013). Since then, the interest on this topic continues to flourish especially with the development of theories and approaches in the study of intelligence happening at the same time with the development of psychology as a unique and scientific discipline (Kaufman, 2013).

Presently, the most widely used and accepted among these theories of intelligence is the Cattell-Horn-Caroll (CHC) theory. The CHC theory divides General intelligence symbolized by (*g*) into different broad abilities. Among these broad abilities, the most distinct are the Crystallized intelligence and Fluid intelligence, represented by (Gc) and (Gf), respectively (McGrew, 2009). On one hand, Crystallized intelligence is the knowledge-based ability that is very reliant on acculturation and education while Fluid intelligence on the other hand, is the ability to solve new and novel problems by reasoning, which is assumed by Cattell to be mainly operated by biological and neurological factors.

Moreover, fluid intelligence is considered as one of the strongest predictors in educational and professional domains, and has been found to be a key component in learning. (Dreary, Stand , Smith and Fernandez, 2007). High performance in such tests is also predictive of broad success like social well-being and mental health (Jensen, 1998).

There have been numerous and significant on-going debates to determine whether the nature of intelligence is either fixed or dynamic. Some evidences pointed out the strong hereditary element of intelligence. Researches that aim to improve fluid intelligence through training generally resulted in indecisive results, implying the relatively fixed nature of intelligence (Sternberg, 2008).

Furthermore, aside from the debate on the dynamism of intelligence, the necessity to obtain an exhaustive understanding of intelligence comes to the fore as it is always a critical factor in the performance of any task whether the latter involves work or daily living, has become an impetus to undertake this study. Intelligence has been acknowledged to be a critical factor in an individual's success throughout his or her lifetime whether in school, in earning a living, as well as, performing daily life activities

According to WM (Wiley, Jarosz, Cushen and Colflesh, 2011), the recent prospect of improving working memory through training has raised the possibility of concomitant improvement in GF. For instance, recent studies such as the one conducted by Jaeggi and colleagues (2008; 2010) found out that working memory training such as the "*n*-back task" can increase the performance gains on fluid intelligence.

On the national and local levels, there has been a proliferation of psychological and educational seminars and programs that are intended to help individuals become more effective in the various aspects of life. Examples of these include Brain Train School of Positivity in Bacolod City. These programs emphasize the importance of memory techniques to have an edge in life.

In the researcher's experience as a teacher, he has learned that there are students who would even resort to taking medications just to improve memory so that they can cope with examinations.

Though there had been tremendous research done on the topic of intelligence and working memory, and most of these, unfortunately, are foreign. What remains to be seen is whether the findings of these existing studies are also true in the Philippine setting.

Given this context, the researcher embarked on this research study with intent of determining the effectiveness of working memory training in improving fluid intelligence, particularly among Filipinos. This study may hopefully become a rich source of solid information to address the current concerns, specifically, of professionals such as psychologists, psychometricians, educators, other allied professions, as well as families and society, in general.

This research aimed to determine the effects of working memory training on the fluid intelligence level of high school students in a public high school in Pulupandan, Negros Occidental. Specifically, it intended to answer the following questions:

1. What is the profile of the participants in terms of: a. Sex; b. Household Monthly Income; and c. Academic Performance?
2. What are the fluid intelligence levels of the control group before and after the intervention?
3. What are the fluid intelligence levels of the experimental group before and after the intervention?
4. Is there a significant difference in the fluid intelligence level of the control group before and after the intervention?
5. Is there a significant difference in the fluid intelligence level of the experimental group before and after the intervention?
6. Is there a significant difference in the fluid intelligence levels of the control and experimental groups after the intervention?
7. What profile variables predict the gains in working memory training of the participants in terms of: a. Sex; b. Household Monthly Income; c. Academic Performance?

Given the inferential objectives of the study, the following null hypotheses were formulated:

1. There is no significant difference in the fluid intelligence level of the control group before and after the intervention.
2. There is no significant difference in the fluid intelligence level of the experimental group before and after the intervention.
3. There is no significant difference in the fluid intelligence levels of the control and experimental groups after the intervention.

This experimental research was anchored on Cattell-Horn-Carroll (CHC) theory of intelligence. The CHC (Cattell-Horn-Carroll) theory is the most widely used theory in IQ testing. This theory is the integration of the Cattell-Horn theory of fluid and crystallized intelligence and Carroll’s (1993) Three-Stratum Theory. Both the Cattell-Horn and Carroll models essentially started from the same point—Spearman’s g-factor theory. Though these authors took different paths, they ended up having remarkably consistent conclusions about the field of broad cognitive abilities. Cattell built upon Spearman’s g to postulate two kinds of g: fluid intelligence (Gf), the ability to solve novel problems by using reasoning—believed by Cattell to be largely a function of biological and neurological factors—and crystallized intelligence (Gc), a knowledge-based ability that is highly dependent on education and acculturation (Horn & Cattell, 1966).

The CHC model is perhaps the most comprehensive and research-based among human cognitive abilities (McGrew, 2005). It is a synthesis of the extended Gf-Gc theory (Horn & Blankson, 2005; Horn & Masunuga, 2000) and the three-stratum theory of cognitive abilities (Carroll, 2003). A hierarchical structure highlights cognitive abilities that vary according to the level of generality: narrow abilities (stratum I), broad abilities (stratum II), and g (stratum III). Narrow abilities include around 70 abilities that are limited in scope and specialized. Broad abilities include Fluid Reasoning, Crystallized Intelligence, Short-Term Memory, Visual Processing, Auditory Processing, Long-Term Storage and Retrieval, Processing Speed, Reading and Writing, Quantitative Knowledge, and Reaction Time/Decision Speed. At the apex of this hierarchical model is g or the general intelligence. The CHC theory provides researchers and practitioners with a standard nomenclature that can facilitate scholarly exchanges regarding the role of cognitive abilities in the acquisition and maintenance of reading skills (McGrew, 1997).

Fluid intelligence (Gf) is a complex cognitive ability that allows humans to adapt their thinking to new problems or situations flexibly. The concept has been defined as "an expression of the level of complexity of relationships which an individual can perceive and act upon when he does not have recourse to answers to such complex issues already sorted in memory" (Cattell, 1971). In other words, Gf can be thought of as the ability to reason under novel conditions and stands in contrast to performance based on learned knowledge and skills or crystallized intelligence (Haavisto & Lehto, 2005; Horn & Cattell, 1967)

Moreover, fluid intelligence was characterized by general, innate abilities to solve novel problems. Individuals with high fluid mental abilities could solve problems that they were not familiar with or had not encountered before without much difficulty. They would be able to identify and discriminate relations between objects and abstract elements better than those with lower fluid abilities. This mental ability increased with age in childhood and after adolescence or early adulthood, this ability would begin to decline slowly. Fluid intelligence was suggested as the ability responsible for the inter-correlations among mental ability tests or Spearman's general factor, g (Cattell, 1943).

Working memory (WM) is a construct that has been studied extensively in the past 50 years, since it was first mentioned by Miller, Galanter, and Pribram (1960), and especially since the influential WM model proposed by Baddeley and Hitch (1974). The concept is a more dynamic version of the short-term memory construct that was present in initial information-processing models (e.g., Atkinson & Shiffrin, 1968). WM has been studied extensively not only in cognitive psychology, but also in other areas, including social, clinical, developmental, and personality research. WM is critical to activities involving the goal-directed use of immediate memory, the maintenance and manipulation of recently attended information, and switching and scheduling task priorities in multitasking situations (Reddick & Lindsey, 2013).

Working memory (WM) has been defined as a system for holding and manipulating information over brief periods of time, in the course of ongoing cognitive activities. Most theorists in the field agree that WM comprises mechanisms devoted to the maintenance of information over a short period of time, also referred to as short-term memory (STM), and processes responsible for cognitive control that regulate and coordinate those maintenance operations (Cowan et al., 2005; Engle, 2010). WM is often assessed by complex span tasks that involve the simultaneous processing and storage of information (Daneman & Carpenter, 1980). An example of such task is counting span, in which participants are asked to count a particular class of items in successive arrays and to store at the same time the number of target items in each array (Case, Kurland, & Goldberg, 1982). These complex span measures stand in contrast to simple span tasks that require only the storage of information with no explicit concurrent processing task. A typical simple span task is digit span, requiring the immediate recall of lists of digits.

Meanwhile, Gottfredson in 1997 echoed that the cognitive training literature has seen an explosion of recent interest in exploring the claim that gains in working memory (WM) training might transfer to gains on measures of fluid intelligence (Gf). If this is true, the implications for academic, professional, and personal success are considerable.

As mentioned in the conceptual pieces of literature above, one of the core processes driving Gf, as well as other higher cognitive abilities, is WM (Wiley, Jarosz, Cushen, & Colflesh, 2011). The recent prospect of improving WM through training has raised the possibility of concomitant improvements in Gf (von Bastian & Oberauer, 2013). More specifically, the *n*-back task, which requires not only the storage and continual updating of information in WM but also interference resolution, has been used widely in WM training studies that explore transfer to Gf. The *n*-back task involves a serial presentation of a stimulus (e.g., a shape), spaced several seconds apart. The participant must decide whether the current stimulus matches the one displayed n trials ago, where n is a variable number that can be adjusted up or down to respectively increase or decrease cognitive load. In the perspective of WM training, efforts have focused on flexibly adapting the task difficulty by the participant's varying performance level by increasing and decreasing the level of *n*. The notion is to keep the participant's WM system continually engaged at its limit, thereby stimulating an increase in WM function, which may then translate into more general improvements in tasks that rely on the integrity of WM skills, such as Gf (Jaeggi, et al., 2008).

Using a dual *n*-back task Jaeggi, et al. (2008) established that significant near transfer to STM had occurred after 19 consecutive days of training. However, there was no significant change in reading span within this timeframe. Each training day comprised 20 blocks that were required to be completed in a single contiguous 25-minute session. In a more recent paper Jaeggi, et al. (2010) compared the transfer efficacy between dual and single *n*-back training tasks, finding that neither task was effective in improving operations span after 20 consecutive training days, completing 15 blocks each daily session. However, Seidler and associates in 2010, reported transfer to operations span using dual *n*-back training over a 17 to 25-day duration.

Additionally, in 2010 Jaeggi et. al's work was replicated for the first time by Stephenson and expanded the experiment they conducted. This study included 110 participants from California State University and Claremont Colleges in the United States. Stephenson divided the participants into five (5) groups; four (4) experimental groups using different variations of the *n*-back task and one (1) passive control group. The duration of training was almost similar to that of Jaeggi (2008). As a result, the replication study demonstrated gains in fluid intelligence among the participants as measured by Raven's Progressive Matrices after a month of *n*-back training, thus, affirming the results of this research.

On the other hand, Preece (2012) replicated the study of Jaeggi and her colleagues, but instead of a no-contact control group, he utilized an active control group. Preece's analysis revealed no significant difference between the training groups concerning performance on the Figure Weights subtest, suggesting that the *n*-back task was not effective in increasing fluid reasoning ability. These findings were in disagreement to those of Jaeggi, et al. (2008; 2010) and suggested that differences between the working memory group and control group found in these studies were likely the result of placebo/motivational effects rather than the properties of the *n*-back task itself. The same conclusions were yielded by Shipstead et al. (2010), Sternberg (2008) and Morrison and Chein (2011). Their proposal that increases to fluid intelligence in previous studies were possibly the result of motivational/expectancy effects rather than the properties of the training task (*n*-back) is consistent with the lack of result reported in this study.

Also, two recent, widely publicized training studies used active controls and failed to find a transfer to measures of Gf (Harrison et al., 2013; Redick et al., 2013). Noting, however, that their active control groups did not improve over baseline, nor did they outperform their associated passive control groups, suggesting that the failure to find transfer was irrespective of control type.

After a thorough review, the previous literature reiterates the role of working memory and fluid intelligence in the cognitive activities of any person. The importance of these concepts is enticing and worthy of investigation. Furthermore, intelligence continues to be a controversial topic in the field of psychology – from its nature, the way it was conceptualized and the manner it was measured. Adding to these controversies is the notion that working memory training may improve fluid intelligence as shown by the group of Jaeggi (2008; 2010). Conflicting results from previous studies of Preece (2012), Shipstead et al. (2010), Sternberg (2008) and Morrison and Chein (2011) yet deepened the controversy.

With this in mind, working memory nonetheless plays an important role in fluid intelligence and as much as it is important in human intelligence as a whole likewise proves to be essential to every person as it is critical in satisfying the maturity demands of every developmental stage of life.

These insights from different studies showed indecisive results and experimental studies are mostly taken outside the Philippine setting. Thus, this study was conducted to corroborate further and expand the finding that working memory training actually improves fluid intelligence.

METHODOLOGY

This is a true experiment utilizing the Randomized Two-Groups Design. In this design, subjects in one group received one level of the independent variable, and those in another group received another level of the independent variable (Leary, 1991). For this particular study, one group is an experimental group that receives an independent variable in the form of *n*-back task and the other is a control group with no contact in terms of the independent variable/intervention given to the experimental group.

Multi-stage sampling was employed in identifying the participants in this study. Multi-stage sampling involves several stages or phases in drawing the samples from the population. In this design, population units are grouped and arranged into hierarchical order or level, and sampling is done successively (Ardales, 2008).

Three levels of randomization were used for this study. At the first level, among five (5) year levels (Grades 7 to 11), Grade 10 was selected through simple randomization. Upon determining the year level, one of the sections of the Grade 10 (Sections 1 to 6) was randomly selected, and in this case, Section 5 was selected. The third level randomization was employed for the assignment of participants to either the control or experimental groups using a computer random number generator. Numbers that were generated corresponded to a particular student of Grade 10 Section 5. These students whose numbers were selected by the random number generator were assigned to the experimental groups. The remaining students who were not chosen were assigned to the control group.

The fluid intelligence level of the participants was determined using the Culture Fair Intelligence Test (CFIT). This test was constructed by Raymond B. Cattell in an attempt to produce a measure of cognitive abilities that accurately estimated intelligence devoid of sociocultural and environmental influences. Its latest edition was printed in 1973.

The *n*-back task introduced by Wayne Kirchner is a continuous performance task that is commonly used as an assessment in cognitive neuroscience to measure a part of working memory and working memory capacity (Gazzaniga, et. al, 2009). Stimuli in the *n*-back task can be presented in either visual or auditory modalities. In a common variant of the visual spatial *n*-back, participants are presented with a grid and have to keep track of a visual stimulus which moves to another location in the grid every few seconds (Jaeggi et al., 2008).

Pre-experiment. First, prior to the experiment, the researcher sought the permission of the school principal of the target participants for the conduct of this research. Once approved, the researcher coordinated with the principal to discuss the nature of the research such as the time frame of the intervention, the software to be installed on the computer, the pilot test before the actual experiment and its possible implications.

Secondly, the researcher conducted the pilot test of the *n*-back training to identify possible problems and issues, find solutions to resolve such problems, and ensure control over possible extraneous variables. There were eighteen (18) Grade 9 students who participated in the pilot testing. A run-through of the program including actual demonstration and instructions were made.

During the pilot testing, the problems encountered by the researcher were the time spent to gather the participants, the computer screens were projecting different levels of brightness (i.e. some were dimmer than the others and some were too bright), and the constant inquiries made by the participants while the testing is going on. Nonetheless, these problems were addressed and immediately resolved by the researcher prior to the experiment proper. The researcher constantly reminded the participants to come on time during their training, uniformly adjusted the brightness levels of all the computer screens, and clearly gave the instructions and clarified all their inquiries.

Thirdly, the researcher randomly selected the year level to be covered in this study. The year level was determined through simple randomization. After identifying the year level, one section from that year level was selected. Having selected the section, the list of students for that section was obtained from the principal. Students of the selected section were informed about the nature of the research and were asked to read the assent form in the presence of one of his/her parents. Once all standard operating procedures have been followed, the participants were randomly assigned to the control and experimental groups through a computer randomizer.

Experiment Proper. The intervention phase commenced with the administration of the CFIT. First, the researcher scheduled the administration of the pretest. As soon as the schedule had been finalized, the researcher administered the CFIT in one of the school's classrooms. Approximately, the test administration including the verbatim instruction lasted for 25 minutes. Test materials such the text booklet and answers sheets were provided as well pencils. A timer was used to time the test. Scores were determined the day after the administration.

Three days after the pretest, the intervention was given. Like the pilot test, the actual training was done the school's computer laboratory which is air-conditioned, well-lighted and sound proof. The training lasted for a period of four weeks, 3 times a week for 20 minutes each session. Each session as scheduled by the principal and agreed by the participants commenced at 8:30 in the morning every Monday, Wednesday and Friday.

The average *n*-back level for each session consisting of twelve (12) rounds was recorded in the upper right portion of the screen. Before every session ends, the researcher noted downs each participant's *n*-back level.

Attrition and missed training sessions was a concern for this study; therefore, strict criteria were set in case a person missed a training session. First, if the participant did not show up for the first two training sessions, then they were not allowed to continue the study. Second, if a participant missed a training session, then they were allowed to make up the training session on the following day by doing two training sessions. However, participants were not allowed to make up more than two training sessions.

Of the original twenty (20) participants in the experimental group, four (4) participants were dropped from the training comprising twenty percent (20%) attrition rate.

Post Experiment. Lastly, three days after the termination of the intervention the posttest was administered by the researcher using the same CFIT that was used for the pretest. Data gathered were collated and encoded in the computer for tabulation and data analysis. After the data analysis, results were interpreted to answer the objectives of the study.

RESULTS, DISCUSSION AND IMPLICATIONS

Females constitute majority of the sample at 54.30%. In terms of the household monthly income, majority of the participants belonged to the "low income class" comprising 74.30% of the sample and followed by the "lower middle-income class" at 25.70%.

The most common grade point average (GPA) that measures the academic performance of the participants falls in the "Fair" cluster at 68.60%, followed by "Good" at 20%. The participants belonging to the "Poor" cluster comprise only 11.40% of the participants.

As for fluid intelligence levels of the control group before and after the intervention, results show that the control group obtained an average score of 13.79 (SD=2.55) in the CFIT before the intervention. Afterwards, on the posttest, the participants had a mean score of 13.84 (SD=2.69). Scores for both the pretest and the posttest are interpreted as low. Furthermore, the standard deviation for the mean scores shows a little variation in the individual scores of the participants.

Talking about the difference in the fluid intelligence levels of the control group before and after the intervention, a [t(19)=-

.213. p=.834], at 95% confidence level was observed. It has established that there is no statistically significant difference in the control group participants' pretest and posttest scores. Therefore, null hypothesis was rejected.

This result, in relation to the experimental group matched the outcomes produced by the study of Jaeggi and colleagues (2008) and Stephenson (2010). Both studies yield a statistically significant difference in the fluid intelligence level of their participants in the experimental group after undergoing the *n*-back task. The two studies also seen an a slight increase in their control group's fluid intelligence level, however, these increased is small enough to be considered statistically significant.

In terms of the fluid intelligence levels of the experimental group before and after the intervention. Results indicate that prior to the intervention the experimental group obtained a mean score of 15.13 (SD=2.80) in the CFIT. Subsequently after the intervention the participants yield an average score of 16.31 (SD=2.41). Mean scores for the pretest and posttest are interpreted as low average. In addition, the standard deviation shows a slight variation in the score of each participant before and after the intervention.

In terms of the difference between the fluid intelligence levels of the experimental group before and after the intervention, a [t(16)=-3.23, p=0.006], at 95% confidence level was observed. It may be concluded that there is a statistically significant difference in the experimental group participants' pretest and posttest scores. Therefore, results reject the null hypothesis.

The result of this study mirrored the result of the experiment conducted by Jaeggi and her group in 2008. They concluded that working memory training can significantly transfer improvement to fluid intelligence. Their study, conducted among seventy (70) participants, had four (4) experimental groups – each group differed on the duration of the *n*-back training; 8, 12, 17, and 19 days. The control group was also divided into four group matching the same duration that of the experimental group. Both groups were subjected to a pretest and posttest that measures fluid intelligence. The researchers reported that participants in the experimental group that undergone the *n*-back training significantly improved their scores on fluid intelligence.

Comparing the means of the two (2) groups, it can be observe that a [t(35)=2.83, p=.008], at 95% confidence level indicates a statistically significant difference score. The score of the experimental group is significantly higher than the control group. In this case the null hypothesis is rejected.

Additionally, the result of the study yields an effect size with Cohen's *d*=0.97, indicating that the average participant in the experimental group is 0.97 standard deviations above the average participant in the control group, therefore exceeding the scores of approximately 83% of the control group.

Multiple regression analyses were conducted to examine the various potential predictors in gains in working memory training. The multiple regression model with all three possible predictors produced R^2 = .0.56, F(2, 16) = 2.38, p=.868. This indicates that all the three (3) profile variables included in this study did not contribute to the multiple regression model. Moreover, these three (3) variables accounted for 23.7% of the variance in the gains in working memory training.

These results suggest that the participants' sex, household monthly income and academic performance, could not account for a significant amount of the variance in their improvement on the working memory training.

This study aimed to determine the effect of working memory training as operationalized by the n-back task on the fluid intelligence of high school students. The *n*-back task was introduced to the experimental group to see its effect on the fluid intelligence of the participants. After the intervention, a significant increase in the fluid intelligence level of the participants in the experimental group was observed and can be accounted to the *n*-back task. This implies that working memory training can increase one's fluid intelligence.

However, results suggest that the participants' sex, household monthly income, and academic performance, could not account for a significant amount of the variance in their improvement on the working memory training.

CONCLUSION AND RECOMMENDATIONS

The results of this experimental study pointed out to the strong evidence of malleability of intelligence as previously claimed by Sternberg as relatively fixed. This research affirmed and replicated the results of the study piloted by the group of Jaeggi (2008) as demonstrated by gains in the scores in the fluid intelligence of the participants as indicated by the Culture Fair Intelligence Test after completing a month long training on working memory in the form of *n*-back task. Results suggest that improving one's working memory (a narrow ability in the CHC model) may increase fluid intelligence (a broad ability in the CHC model), thought to be a distinct and separate abilities in the CHC model.

These findings may have impact on the academe, education sector as well as professional development. In terms of the academe, the findings contribute to the existing theory on memory as a primary component of intelligence. It is a rebuttal against those that claim working memory is separate and distinct from fluid intelligence. In the field of education, the findings of the study serve as a robust and scientific proof that the *n*-back exercises can be very well adopted as a teaching intervention across age groups. Lastly, working memory training may be helpful for professionals. Day-today problem solving requirements in the workplace may be addressed when a person's fluid intelligence is more efficient.

Moreover, variables such as sex, academic performance, and household monthly income contribute little in the gains of working memory training and deemed to be as not significant predictors. What predicts gains in working memory is yet to be known. This research may contribute to the limited literatures that investigate ways to improve intelligence.

In light of the findings and conclusions of this study, the researcher recommends the following:

That students, involve themselves in working memory training to increase their capacity to become practical problem solvers and effective learners.

That parents, take some time to engage their children in working memory training and be aware that intelligence includes other broad abilities like fluid intelligence, therefore, undermining the notion that intelligence is purely crystallized.

That teachers, adopt teaching strategies and schemes that give emphasis on enhancing working memory.

That school administrators, design a program of instruction that allows the students to enhance their working memory, one such program is to expose students to the n-back task by installing this program in their school computers.

That guidance counselors, develop a guidance program in the realm of academic counseling that includes training one's working memory to help students become effective learners.

That psychologists, make use of interventions such as training on working memory in their effort to improve and understand the dynamics of intelligence.

That future researchers, replicate this study by introducing variations of *n*-back task such as the dual *n*-back and to add an active control group together with the experimental and control group to have a clearer understanding of the dynamics of such effects.

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