THE RELATIONSHIP BETWEEN WORKING MEMORY CAPACITY AND FLUID INTELLIGENCE

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Abstract

Working memory is the ability to simultaneously maintain, store and process information.
Fluid intelligence is the ability to solve new problems, use logic in new situations, and identify patterns. The present research investigated the relationship between working memory capacity and fluid intelligence. The present research adheres to correlatioal research design. 100 middle school students were selected as samples (Non probability – purposive sampling). Working Memory Index (WMI) Subset of The Wechsler Intelligence Scale for Children IV (WISC-IV) was used to measure working memory and Raven's Standard Progressive Matrices was used to measure fluid intelligence. Data analysis revealed that there was not significant correlation between working memory and fluid intelligence with $r = 0.08$ at $p > 0.05$. Hence, it is evidently proved that there is only weak relationship between working memory and fluid intelligence.

Key words: Working memory, Fluid Intelligence.

Introduction

The present research investigated the relationship between working memory and fluid intelligence.Working memory is the term that cognitive psychologist use to describe the ability to simultaneously maintain, store and process information (Baddeley & Hitch, 1974). Working memory can be characterized as a system that holds a small number of representations temporarily available for goal-directed processes (Oberauer & Lange, 2009). The ability to maintain information in an active and readily accessible state, while concurrently and selectively processing new information, is one of the greatest accomplishments of the human mind. (Kane, M. J., Conway, A. R., Hambrick, D. Z., & Engle, R. W. 2007)

Numerous studies have been conducted on various facets of the working memory and fluid intelligence. Working memory is central to the functioning of the mind. It correlates with many more general abilities and outcomes – things like intelligence and scholastic attainment– and is linked to basic sensory processes (Alex Burmester 2017). Working memory capacity and fluid intelligence have been demonstrated to be strongly correlated traits. Typically, high working memory capacity is believed to facilitate reasoning through accurate maintenance of relevant information. In this article, we present a proposal reframing this issue, such that tests of working memory capacity and fluid intelligence are seen as measuring complementary processes that facilitate complex cognition. Respectively, these are the ability to maintain access to critical information and the ability to disengage from or block out dated information. In the realm of problem solving, high working memory capacity allows a person to represent and maintain a problem accurately and stably, so that hypothesis testing can be conducted. However, as hypotheses are disproven or become untenable, disengaging from outdated problem solving attempts becomes important so that new hypotheses can be generated and tested. From this perspective, the strong correlation between working memory capacity and fluid intelligence is due not to one ability having a causal influence on the other but to separate attention-demanding mental functions that can be contrary to one another but are organized around top-down processing goals (Zach Shipstead, Tyler L. Harrison, and Randall W. Engle 2016).

The concept of working memory capacity as a determinant of fluid intelligence is so well accepted that much of the training literature relies on increases in fluid intelligence (or lack thereof) as a criterion for judging the efficacy of interventions (Au et al., 2015). Numerous studies have found near-perfect and even perfect correlations between working memory capacity and fluid intelligence (Shipstead, Lindsey, Marshall, & Engle, 2014). The study aimed to evaluate how well fluid reasoning can be predicted by a task that involves the monitoring of patterns of stimuli. This task is believed to measure the effectiveness of relational integration—the process that binds mental representations into more complex relational structures. In Experiments and, the task was indeed validated as a proper measure of relational integration, since participants' performance depended on the number of bindings that had to be constructed in the diverse conditions of the task, whereas neither the number of objects to be bound nor the amount of elicited interference could affect this performance. In Experiment, by means of structural equation modeling and variance partitioning, the relation integration task was found to be the strongest predictor of fluid reasoning, explaining variance above and beyond the amounts accounted for by four other kinds of well-established working memory tasks (Adam Chuderski 2014).

Working memory capacity is the major determinant of a person's fluid intelligence, it is important to remember that most data regarding the relation between working memory and fluid intelligence have been collected via correlational research (Harrison et al., 2013). The crucial cognitive mechanism underlying fluid ability lies in storage capacity, which enables people to actively maintain distinct chunks of information and flexibly construct task-relevant bindings among them (Chuderski, Taraday, Ne̜cka, & Smolen, 2012). Working memory is a limited capacity part of the human memory system that combines the temporary storage and manipulation of information in the service of cognition. Short-term memory refers to information-storage without manipulation and is therefore a component of working memory. Working memory differs from long-term memory, a separate part of the memory system with a vast storage capacity that holds information in a relatively more stable form. According to the multi-component model, working memory includes an executive controller that interacts with separate short-term stores for auditory-verbal and visuo-spatial information. The concept of working memory has proved useful in many areas of application including individual differences in cognition, neuropsychology, normal and abnormal child development and neuroimaging (Alan Baddeley and Graham J. Hitch 2010).

A key motivation for understanding capacity in working memory (WM) is its relationship with fluid intelligence. Recent evidence has suggested a two-factor model that distinguishes between the number of representations that can be maintained in WM and the resolution of those representations. To determine how these factors relate to fluid intelligence, we conducted an exploratory factor analysis on multiple number-limited and resolution-limited measures of WM ability. The results strongly supported the two-factor model, with fully orthogonal factors accounting for performance in the number-limited and resolution-limited conditions. Furthermore, the reliable relationship between WM capacity and fluid intelligence was exclusively supported by the number factor (r = .66), whereas the resolution factor made no reliable contribution (r = -.05). Thus, the relationship between WM capacity and standard measures of fluid intelligence is mediated by the number of representations that can be simultaneously maintained in WM, rather than by the precision of those representations (Keisuke Fukuda et al, 2010).

Nearly 1,000 adults performed a battery of cognitive tests and working memory tasks requiring simultaneous storage and processing of information. Because the amount of to-be-remembered information, or set size, varied randomly across trials, the relation between fluid intelligence and working memory could be examined across different levels of complexity and across successive trials in the working memory tasks. Strong influences of fluid intelligence were apparent in the simplest versions and on the initial trials in the working memory tasks, which suggests that the relation between working memory and fluid intelligence is not dependent on the amount of information that must be maintained, or on processes that occur over the course of performing the tasks. (TA. Salthouse and J E. Pink 2008).

Examined individual differences in the number and resolution of representations in WM found no correlation between these measures (despite having established the internal reliability of each measure). That is, subjects who could maintain the largest number of items in working memory were not necessarily the subjects who had the clearest memories, instead of subdividing intelligence into fluid intelligence and crystallized intelligence (i.e., acquired knowledge), split intelligence into verbal and non-verbal intelligence. He used the Block Design subtest from the WAIS-R, the cube comparison task from the Educational Testing Service (ETS) kit, and Raven's Advanced Progressive Matrices to measure non-verbal intelligence. WM measures used in study included Reading Span and Computational Span Task. The correlations between WM measures and Raven's Advanced Progressive Matrices were 0.20 and 0.43. The correlations between scores on non-verbal intelligence and WM ranged from −0.08 to 0.45. On processing speed, WM, and fluid intelligence used the Raven's Standard Progressive Matrices to measure fluid intelligence and four modified simple memory span tasks to assess WM. These tasks required participants to recall digits or positions and the color of these stimuli in the same or reverse order. The impact of WM on fluid intelligence was statistically significant even after the influences of age and processing speed had been statistically controlled for in their path analysis. The coefficient of the causal path from WM to fluid intelligence was 0.38 (Awh, Barton and Vogel, 2007).

Working memory (WM) enables the active maintenance of information in a readily accessible state. In addition to its core role in most large-scale models of cognition a central motivation for research on working memory is that it exhibits robust correlations with broader measures of intellectual ability such as scholastic aptitude and fluid intelligence. The link between WM capacity and fluid intelligence has been observed across a broad range of experimental paradigms. One prominent approach has demonstrated correlations between fluid intelligence and WM capacity estimated using "complex span measures" that were designed to tap into both storage capacity and processing aspects of WM ability (Cowan et al, 2006). While most have claimed that WM and fluid intelligence are closely related but not identical. In addition to the on-going uncertainty about the measurement of WM, measures of fluid intelligence varied. Moreover, different terms for fluid intelligence were used interchangeably, such as "nonverbal intelligence", "reasoning ability", "g", "general fluid intelligence", and "intelligence". In addition, different statistical methods were used to examine the relationship between WM and fluid intelligence. This variation in measurement, terminology, and statistical methods might have contributed to reaching different or even conflicting conclusions about the relationship between WM and fluid intelligence (Kane, Hambrick, & Conway, 2005).

He examined the relationship between fluid intelligence and WM capacity measured in a simple change detection task. Here, observers saw an array of multiple colored squares and then after a brief delay indicated whether or not any of the items in a subsequent test array had changed or not. Although this task did not impose any other attention-demanding tasks or interfering stimuli, the resulting estimates of WM capacity were reliably correlated with fluid intelligence. Thus, pure storage capacity alone is linked with the broader construct of fluid intelligence (Cowan et al. 2005). This wide range of correlation coefficients has led to conflicting ideas about the nature of the relationship between WM and fluid intelligence, it is widely accepted that WM is a strong predictor of fluid intelligence but not identical to it (Kane, Hambrick, & Conway, 2005). It was cited in many of the aforementioned studies of WM and fluid intelligence. They used the term "reasoning ability" in their study and described as "at or near the core of what is ordinarily meant by intelligence" and equated it to general fluid intelligence. They used 15 reasoning tests to measure reasoning ability, some of which required mathematical or grammatical skills and word knowledge. The correlation between these reasoning tests and Kyllonen and Christal's WM measures ranged from 0.80 to 0.90 (Kane & Hambrick, 2004).

In the present research it was hypothesized that: There will be weak relationship between working memory capacity and fluid intelligence.

Method

Participants

Data were reported for 100 students (59 girls and 41 boys) with a mean of 12 years 9 months (range 11 years 0 month to 15 years 1 month, SD 0.9 year). All the students were attending state board schools in Chennai.

Materials

Working Memory Index (WMI) subset of the Wechsler Intelligence Scale for Children IV (WISC-IV) developed by David Wechsler is used to measure working memory of children from 6 to 16 years. The WMI of WISC-IV has two core subtests namely: digit Span, letter-number sequencing, one supplementary subtest – arithmetic. The digit span has two components namely, digit span forward which requires the child to repeat numbers in the same order the examiner reads aloud, digit span backward which requires the child to repeat the numbers in the reverse order presented by the examiner. In letter number sequencing child is presented a series of numbers and letters. The child repeats numbers then letters in order. In Arithmetic, The child mentally solves a series of orally presented arithmetic problems within a specified time limit. Reliability: The subtest reliability coefficients for internal consistency ranged from .79 to .90 with a median of .86. These coefficients showed substantial improvement from those of WISC-III subtests. The index scores reliability coefficient ranged from .88 PSI to .97 FS with a median of .92. These are identical to or slightly higher than WISC-III corresponding scales. Validity: One of the manual reports strong correlations between WISC-IV metrics and comparable metrics from the WISC-III WPPSI-III, WAIS-III, Wechsler Abbreviated Scale of Intelligence, WIAT-II, Children's Memory Scale, Gifted Youth Version, and the Adaptive Behavior Assessment System-Second Edition. Evidence of construct validity was also established using matched samples of clinical and non-clinical children.

Raven's Standard Progressive Matrices was used to measure fluid intelligence. Population age group is from 6 to adult. Time duration of the test is 45 minutes. J.C. Raven is the author. The SPM consists of 60 items arranged in five sets (A, B, C, D, & E) of 12 items each. Each item contains a figure with a missing piece. Below the figure are either six (sets A & B) or eight (sets C through E) alternative pieces to complete the figure, only one of which is correct. Each set involves a different principle or "theme" for obtaining the missing piece, and within a set the items are roughly arranged in increasing order of difficulty. The raw score is typically converted to a percentile rank by using the appropriate norms. Reliability: Internal consistency studies using either the split-half method corrected for length or KR20 estimates result in values ranging from .60 to .98, with a median of .90. Test-retest correlations range from a low of .46 for an eleven-year interval to a high of .97 for a two-day interval. The median test-retest value is approximately .82. Coefficients close to this median value have been obtained with time intervals of a week to several weeks, with longer intervals associated with smaller values. Raven provided test-retest coefficients for several age groups: .88 (13 yrs. plus), .93 (under 30 yrs.), .88 (30-39 yrs.), .87 (40-49 yrs.), .83 (50 yrs. and over).Validity:Spearman considered the SPM to be the best measure of g. When evaluated by factor analytic methods which were used to define g initially, the SPM comes as close to measuring it as one might expect. The majority of studies which have factor analyzed the SPM along with other cognitive measures in Western cultures report loadings higher than .75 on a general factor. Concurrent validity coefficients between the SPM and the Stanford-Binet and Weschler scales range between .54 and .88, with the majority in the .70s and .80s.

Procedure

In order to begin the research, an introductory session on working memory, its importance and fluid intelligence were rendered. Informed consent was obtained from the samples. Then students were given research roll number. Each child was tested individually in a quit area of the school were tested with Working Memory Index (WMI) Subset of The Wechsler Intelligence Scale for Children IV (WISC-IV) to measure working memory and Raven's Standard Progressive Matrices for fluid intelligence Gf. All participants were thanked for their participation.

Results

Figure 1 and Figure 2 represents the graphical illustration of working memory and fluid intelligence scores respectively. It is vivid that both the variables have above average performances. Table 1 provides the descriptive statistics for working memory and fluid intelligence scores.

Fig: 1 Graphical illustration of Working Memory scores	Fig: 2 Graphical illustration of fluid Intelligence score
* x axis : Working Memory scores y axis : no. of students	* x axis : Fluid Intelligence scores y axis : no. of students

Table: 1 Descriptive statistics for Working Memory and Fluid Intelligence

	Working memory	***Fluid Intelligence***
Mean	14.45	45.71
Standard deviation	1.1	3.28
Range	5	12
Skewness	0.93	-0.18
Kurtosis	4.11	1.89

Subsequent analyses focused on correlation between working memory and fluid intelligence scores. Correlation co-efficient of working memory and fluid intelligence scores were computed in table 2. It is proved that working memory and fluid intelligence scores did not correlate significantly R= 0.08. The P-Value is 0.4. Although technically there is a positive correlation, the relationship between the variables is weak.

Table: 2 Correlation table for Working Memory and Fluid Intelligence

R	0.08*

* $p < 0.05$ (not significant)

Further, linear regression equation is derived [figure 3]. The outcome of research is consistent with the hypothesis that working memory will have a weak relationship with fluid intelligence.

Sample size: 100
Mean x ($\bar{x}$): 14.45
Mean y ($\bar{y}$): 45.71
Intercept (a): 41.874616977225
Slope (b): 0.26542443064184
Regression line equation:
$y = 41.874616977225 + 0.26542443064184x$

* x axis : Working memory score
y axis : Fluid Intelligence scores

Fig: 3 Graphical illustration of the Linear regression equation

Discussion

Working memory capacity was not significantly related to fluid intelligence. A key motivation for understanding capacity in working memory (WM) is its relationship with fluid intelligence. Recent evidence has suggested a two-factor model that distinguishes between the number of representations that can be maintained in WM and the resolution of those representations. To determine how these factors relate to fluid intelligence, we conducted an exploratory factor analysis on multiple number-limited and resolution-limited measures of WM ability. The results strongly supported the two-factor model, with fully orthogonal factors accounting for performance in the number-limited and resolution-limited conditions. Furthermore, the reliable relationship between WM capacity and fluid intelligence was exclusively supported by the number factor ($r = .66$), whereas the resolution factor made no reliable contribution ($r = -.05$). Thus, the relationship between WM capacity and standard measures of fluid intelligence is mediated by the number of representations that can be simultaneously maintained in WM, rather than by the precision of those representations (Keisuke Fukuda et al, 2010).

The conclusion is reinforced by another study WM and fluid intelligence. They used the term “reasoning ability” in their study and described as “at or near the core of what is ordinarily meant by intelligence” and equated it to general fluid intelligence. They used 15 reasoning tests to measure reasoning ability, some of which required mathematical or grammatical skills and word knowledge. The correlation between these reasoning tests and Kyllonen and Christal’s WM measures ranged from 0.80 to 0.90 (Kane & Hambrick, 2004).

One limitation of the present research was assessment of working memory with the dependence of verbally based assessment methods only. The reason for this limitation is that robust method for measuring working memory through non verbal standardized inventory in children age group was not available. As a consequence, it is not possible to make claims about the degree of domain generality of the working memory capacity under assessment.

The implimentation of the study could be used to detect deficits in working memory capaity and fluid intelligence. It emphasis on the cruciality of working memory capacity and fluid intelligence. In conclusion, working memory capacity and fluid intelligence are weakly related to each other.

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