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The relationship between Howard Gardner's Academic and Personal Intelligences and Working Memory

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Abstract
The aim of this research was to explore whether there existed a relationship between Working Memory and Howard Gardner's Theory of Multiple Intelligences, in specific, his Academic Intelligences and Personal Intelligences. To do this, a quantitative assessment was administered to a group of high school students enrolled in AP Psychology at Corvian Community High School. This assessment was intended to test for their Academic Intelligence, which was defined to consist of Logical-Mathematical Intelligence and Verbal-Linguistic Intelligence as well as their Personal Intelligence, which was defined to consist of Interpersonal Intelligence and Intrapersonal Intelligence. Each of these Intelligences were then compared with their Working Memory, which consisted of the Phonological Loop, the Visuospatial Sketchpad, and Central Executive Functioning. It was found that neither Gardner's Academic nor Personal Intelligences possessed a significant correlation with the Working Memory or any of its components. Based on the testing methods used in this study, it was concluded that Howard Gardner's Theory of Multiple Intelligences is not based on cognitive ability due to its lack of a quantitative correlation with Working Memory, a critical cognitive ability.

Keywords
Intelligence, Multiple Intelligences Theory, Working Memory, Phonological Loop, Visuospatial Sketchpad, Central Executive Functioning, Cognitive ability, Howard Gardner, Fluid Intelligence, Crystallized Intelligence

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Introduction

The majority of people are quick to label others as smart or stupid, retentive or forgetful, but, despite these categorizations, Intelligence and memory are far deeper and more complex than the polarized views that so often defines them. Intending to explore these intricacies, this paper studied Working Memory as it relates to the Theory of Multiple Intelligences (MI Theory). The test created for this study is based on that theory, which outlined eight distinct Intelligences. It was first detailed in Howard Gardner's book, *Frames of Mind: Theory of Multiple Intelligences* (1), and was later expanded upon in another one of his books, *Frames of Mind: New Horizons* (2). For the purposes of this study, four of these eight Intelligences were separated into two categories, Academic and Personal. On the other hand, Working Memory is the ability to retain and recall easily accessible information while carrying out other cognitive tasks (3). As such, this paper aimed to find the differences between Working Memory's relationship with Academic and Personal Intelligence in AP Psychology students at Corvian Community High School. It was hypothesized that neither Academic Intelligence nor Personal Intelligence would be highly correlated with Working Memory or with any of its types. To answer this question, the aforementioned population was administered a quantitative assessment to determine their aptitude in Working Memory, its subcomponents, and each of the four tested Intelligences. The approach above was used because it was an objective way to provide each individual participant a score.

Literature review

Intellectual ability

The simple question of "What is Intelligence?" is commonly debated and has been a topic of psychological inquiry for much of human history. Many researchers have attempted to answer this question and many potential answers have been formulated. The first scientifically influential attempt to answer this question was made by Charles Spearman in 1904. He theorized a broad general Intelligence that influences all cognitive abilities (4). Spearman's theory has influenced the modern view of Intelligence, especially in modern-day IQ tests that assess general Intelligence. Later, psychologist Raymond Cattell elaborated on this theory, suggesting general Intelligence was composed of two subcategories: fluid Intelligence (Gf) and crystallized Intelligence (Gc). Gf is a biological concept of Intelligence that people are born with (5). For this reason, Gf tends to be the highest during adolescence and decreases significantly as individuals age (6). On the other hand, Gc is the expression of intellectual ability gained through cultural experiences and education (5). Unlike Gf, Gc continuously increases with age (6). Despite the historical importance of general Intelligence and its adaptations, additional theories have considered more than one intelligence. One example is Robert Sternberg's 1985 Theory of Triarchic Intelligence, which theorized three types of Intelligence: analytical, creative, and practical (7). Sternberg's theory was influenced by Gardner's MI Theory, as it was the first to pose the idea of more than a single Intelligence.

MI Theory comprises eight different types of Intelligence, seven of which were originally established in *Frames of Mind: Theory of*

Multiple Intelligences, including Logical-Mathematical, Verbal-Linguistic, Spatial, Bodily-Kinesthetic, Musical, Intrapersonal, and Interpersonal. Gardner later updated this theory in *Frames of Mind: New Horizons* in which he added Naturalist Intelligence. Each of these Intelligences have different purposes in the daily lives of everyday people and, as such, four of these Intelligences will be split up into categories. The first is the Academic Intelligences which includes Logical-Mathematical Intelligence, the ability to quickly solve relatively basic math problems without showing work and solve abstract logic-based questions, and Verbal-Linguistic Intelligence, the ability to convey and interpret language (1). The second category is the Personal Intelligences which includes Interpersonal Intelligence, the ability to understand the emotions of others, and Intrapersonal Intelligence, the ability to understand one's own emotions (1). These Intelligences are conceptually similar to many other intellectual theories; however, their definitions are distinct.

MI Theory has advanced beyond Gardner in the years following his books' release. For instance, in their 2017 research paper, Shearer and Karanian sought to find concrete evidence for MI Theory. While the evidence they found was not definitive, it was very compelling in favor of the theory. After reviewing evidence from their study, the authors found a clear distinction in the brain based on which Intelligence is applicable in a current situation. Moreover, they found that MI Theory and General Intelligence can co-exist within the brain, especially when considering the separate configurations of each Intelligence (8). Their research demonstrated that there existed more evidence in support of the MI Theory than was previously believed. A separate study conducted in 2021 investigated the distinctions in the Intelligences between overachievers and underachievers in 9th-grade English (9). The study concluded that there was a clear deviation in all of the Intelligences between underachievers and overachievers; however, overachievers did not always receive higher scores (9). Both this study and the one performed by Shearer and Karanian illustrated the continued relevance of MI Theory in modern psychology. Since results in the literature are conflicting, MI theory has both proponents and opponents; even to the extent of being judged to be a myth by the latter group (10). Claims of MI Theory being a "neuromyth" are certainly present and possible; however, "MI Theory is still a plausible, legitimate scientific theory of Intelligence" (10). Overall, MI theory has evidence both in favor and against its tenets and retains relevance, even under pressure of being labeled as pseudoscience.

Memory

Another vital aspect of human cognition is memory, which is how humans store, understand, and recall information (11). Within the concept of memory, there are three subcategories: sensory, short-term, and long-term (11). Each of these subcategories is a piece of the totality of human memory, and each is vital in how the human brain processes information. For instance, sensory memory is the perception from the five main human senses (12). It lasts for very little time but can store unlimited information outside of human consciousness (12). Sensory memory is used every time someone takes advantage of the aforementioned five main senses. On the other

hand, short-term and long-term memory are the more well-known facets of human memory. Short-term memory holds only a limited amount of information and only for a short time (13). Conversely, long-term memory is information encoded in the brain over long periods of time that can be recalled at any given moment (14). Each of these aspects of memory is vital to understanding memory as a whole and how each person remembers different events and experiences. Sensory, short-term, and long-term memory are all essential aspects of human cognition that provide humanity with the necessary awareness for everyday tasks.

While sensory memory and long-term memory are crucial to understanding memory as a whole, this study will largely focus on short-term memory and its qualities and effects. Specifically, this study will focus on individual differences and how memory varies from person to person. These individual differences are defined by the amount of information a person can hold and recall at once, resulting in people with different memory performances (15). A more specific type of short-term memory is Working Memory. Within Working Memory, there are three main subcategories: the Phonological Loop, the Visuospatial Sketchpad, and Central Executive Functioning (16). The Phonological Loop is the capacity to remember auditory, as well as written, information, in large part by vocalizing to oneself what is being read (17). There are two critical aspects of the Phonological Loop with the first being the phonological store which allows people to store information for approximately two seconds (18). In order to help retain this information, the second component, the articulatory rehearsal process, repeats the stored information in order to increase its retention time in the brain (18). Conversely, the Visuospatial Sketchpad is the ability to retain visual and spatial information (19). The reason that the Phonological Loop and the Visuospatial Sketchpad are viewed as two distinct concepts is due to the fact that their respective pieces of information are “kept in separate storage subsystems” (18). Finally, Central Executive Functioning is responsible for allocating human attention to the other two aspects of Working Memory (18). This is especially important because, when it comes to important and cognitively intense tasks, the human brain struggles to multitask, and as such, attention needs to be properly allocated. For this reason, the Phonological Loop and Visuospatial Sketchpad are often considered “‘slave’ systems” to Central Executive Functioning, meaning that they “can be mobilized by the central executive” whenever what they each store needs to be paid attention to (18). Each of the three parts of Working Memory have their own separate functions; however, when looked at together, it becomes evident that they work inside of a system of Working Memory.

Since this study will investigate all three components of Working Memory, it is important to understand the cognitive basis that Working Memory holds in total within the psychological field. Working Memory holds a strong connection with cognitive abilities and Intelligence and serves as a “dissociable cognitive skill” when discussed in comparison to IQ (20). In regards to MI Theory, it seems likely that a correlation with Working Memory could be present, especially considering that “many important cognitive abilities, the same ones that fall under the umbrella of

Intelligence, such as academic achievement, learning, problem-solving, reading comprehension, and reasoning require WM [working memory]" (21). Additionally, Working Memory has been found to predict "subsequent skills in reading, spelling, and math" (20). The connections made with Working Memory in both of these sources are important because problem-solving and skills in math are abilities that should be present in Logical-Mathematical Intelligence and reading comprehension and skills in both reading and spelling should be correlated with Verbal-Linguistic Intelligence. However, this does not inherently guarantee a correlation between any of Gardner's Intelligences and Working Memory since this study does not simply test problem-solving abilities, reading comprehension, or someone's ability to spell, read, or do math. Rather, it tests Gardner's Intelligences in the way that he defines them in his books. As such, it is important to test a defined cognitive ability like Working Memory against a theoretical like Gardner's Intelligences in order to compare how grounded Gardner's Intelligences are in the same cognitive abilities that relate to Working Memory.

Current literature

This literature review specifically focused on two concepts; MI Theory and Working Memory. While Working Memory has been extensively studied and holds a strong cognitive basis, MI Theory is more theoretical with less empirical evidence in its favor and less of a proven foundation in cognitive abilities than Working Memory. As such, comparing MI Theory to Working Memory could possibly find whether or not MI Theory is based on cognition. This is especially relevant because Working Memory has already been compared to different views of Intelligence. For instance, a 2008 study concerning Working Memory and Gf conducted by Salthouse and Pink, found that those with higher Gf tended to have a better Working Memory (22). This connection further implies that, like Working Memory, Gf is a type of cognitive ability. Furthermore, Gf was shown to not just be correlated with Working Memory, but rather, caused by someone's Working Memory capacity (23). This is important because a causal relationship shows even more of a cognitive basis than does a correlation, which means that Intelligence can be seen as something that has a close association with Working Memory. Therefore, findings in this study have the potential to highlight the extent to which Gardner's Theory actually deals with Intelligence.

Working Memory has even shown relationships to skills similar to those that Gardner's Intelligences concern themselves with. A key example of this was found in a meta-analysis produced by Ji et al., which investigated different tests of mathematical problem solving (MPS) and Working Memory (24). The study found that Working Memory did have a significant correlation with MPS (24). Although these results may seem similar to Gardner's Logical-Mathematical Intelligence which Ji's study tested for, the intent of this study is to investigate Gardner's definitions of Intelligence, allowing conclusions to be drawn about whether or not they are truly founded in cognitive ability. Nowbakht et al. performed a study that involved both Working Memory and Gardner's Verbal and Interpersonal Intelligence (25). Their work did not explicitly investigate the relationship between Working

Memory and Gardner's Intelligences. Instead, it was aimed at finding how Working Memory, Verbal Intelligence, Interpersonal Intelligence, and personality influenced the ability to learn English (25). Furthermore, their study did not definitively test for Gardner's Intelligences, rather using self-reported scales not correlated with tests that assess each Intelligence. Hence, there is still a paucity of data in the literature regarding the actual relationship of Working Memory with Gardner's Academic and Personal Intelligences. The work presented in this paper addresses the question: Do Howard Gardner's Academic and Personal Intelligences relate to Working Memory, and, if so, how do each of these Intelligences differ in their relationship with Working Memory? The terms MI Theory, MI, Multiple Intelligences, Multiple Intelligences Theory, MI Intelligences, and Theory of Multiple Intelligences are used interchangeably throughout this paper.

Materials and Methods

Overview

The quantitative study detailed in this paper asked participants a series of questions in order to determine their scores for Academic and Personal Intelligences and each component of Working Memory. A quantitative approach was the best fit for this study, as it was significantly more objective and unbiased than a qualitative approach and, as such, was incorporated to give each participant a definitive quotient regarding their intellectual ability and Working Memory. Additionally, past tests of Intelligence that influenced the methods in this study were similarly quantitative. These quantitative questions were used throughout the online test and consisted of multiple-choice questions, Likert scales, matrix questions, checkbox questions, and short answer questions with a single correct answer.

The sample size of this study was 45 of the 45 students at Corvian Community School who were enrolled in AP Psychology. These responses were collected using a Google Form which was chosen because all students at Corvian Community School have access to these forms, and participants were limited to one response. The Google Form was sent to the AP Psychology teacher so they could administer the test in a single day for both of the classes, which included sophomores, juniors, and seniors. This distribution method allowed a wide variety of students to take this test, especially since, at Corvian Community School, AP Psychology is one of the AP classes with the fewest prerequisites and is, as such, the largest and most diverse.

MI tests

The online test was separated into seven segments, four of which were intended to analyze the intellectual abilities of participants while the other three analyzed their Working Memory. Due to the quantitative nature of this study, each participant was given a quotient for each segment to find correlations between Intelligences and Working Memory.

The first segment determined the Logical-Mathematical Intelligence of participants and was divided into two sections (Appendix B). In total, Gardner defined this Intelligence as the ability to solve complex mathematical and logical problems under a time limit and "invisible[ly]," meaning to be able to answer these questions without writing or speaking the process (2). The first section, composed of eight short answer questions, determined their

mathematical ability based on how well participants could perform calculations under a time limit without showing work. These questions included multiplication, addition, subtraction, division, order of operations, and word problems. After speaking with math teachers at Corvian Community School, it was verified that all high school students had been taught how to complete the concepts underlying the eight short-answer math questions. The logical section, which included five multiple-choice questions, was intended to find how well participants could solve logic-based problems under a time limit. The test used for logical reasoning was adapted from the 1985 Cornell Critical Thinking Test Level X developed by Ennis et al. which gives participants one or more situations that are assumed to be true and asks the participant to determine if a new situation is true based only on the provided information (Appendix D). From this participants must choose, "YES," meaning the new situation must be true, "NO," meaning it cannot be true, and "MAYBE," meaning there was not enough information to draw a conclusion (26). These questions were intentionally designed to make participants think and consider many seemingly minor details.

The second of the Academic Intelligences tested was Verbal-Linguistic. The verbal section of this segment had participants answer three anagram-based questions, each with fifteen scrambled combinations of English words. Five of these were scrambled versions of actual English words and the others were random letters designed to resemble the scrambled versions of real words without being a part of the English language (Appendix E). The first question used three-letter words, the second used four-letter words, and the third used five-letter words. The use of anagrams to test Verbal Intelligence was used and defended by Thomas W. Moon in a graduate-level thesis at Appalachian State University (27). On the other hand, the linguistic section was composed of questions intended to determine participants' ability to comprehend what they read (Appendix E). These four questions were sourced from a practice version of the Digital SAT for students still taking it on paper, which was not an option at Corvian Community High School, making it far less likely that participants would already have been exposed to the questions (28). Participants were provided with a short passage to read and a question regarding vocabulary or comprehension of the passage (28). In total these two sections of the verbal-linguistic test segment determined the ability to comprehend and use the English language.

Interpersonal Intelligence was tested in two different ways. First, participants were given a picture and asked to determine the degree to which the picture expressed the given emotions: happiness, sadness, fear, anger, disgust, excitement, surprise, and anxiety (Appendix F). Participants then ranked each emotion on a scale from one to five, with one meaning the photo expressed none of the given emotions and five meaning the photo expressed an extreme amount of the given emotion. The method used to determine Interpersonal Intelligence in this study was originally conceptualized in the Mayer-Salovey-Caruso Emotional Intelligence Test (MSCEIT), created by John Mayer, Peter Salovey, and David Caruso which tests for Emotional Intelligence based on a person's emotional reactions to a given scenario and their ability to perceive

emotions (29). The other way participants' Interpersonal Intelligence was tested, was also a part of the MSCEIT. In this aspect of the test, participants were presented with a certain situation and asked to rank the usefulness of a set of given emotions when they found themselves in the situation (Appendix F). Participants were presented with a Likert scale ranging from one to five, with one meaning not useful and five meaning very useful. Once combined, this part shows how well each participant could understand and interact with the emotions of others.

The final Intelligence test was to determine Intrapersonal Intelligence, which also used two aspects of the MSCEIT (29). First, participants were presented with a situation and asked how they would react to that situation being changed (Appendix G). These questions were adapted from MSCEIT questions in a way where the subject of the questions was the test-taker. This way, participants answered in the way they would have responded, as opposed to interpreting the intentions of others. The same alterations were made to the second aspect of the MSCEIT that was used to test Intrapersonal Quotient (IAQ), which, once changed, gave participants a situation that they were the subject of. Additionally, participants used a Likert scale to rate the effectiveness of each action in preserving the mood of the given situation, with a score of one, meaning the action was very ineffective and a score of five, meaning the action was very effective (Appendix G). This part of the test determined how well the participants were able to comprehend and control their own emotions.

Working Memory tests

The first aspect of Working Memory, the Phonological Loop, was tested through the memory of written information so that an entire classroom could take the test at once. The test used to assess the Phonological Loop was an adaptation of the Digit Span Task in which numbers appeared and disappeared in a set order and, after watching the video, participants had to recall the numbers and their order (30) (Appendix A). This segment contained nine questions with the first three only including four to six numbers. The next three included four to six letters and the last three included eight characters, either numbers or letters. Immediately after each video showing the digits, letters and characters, participants were asked to recall them, testing both the immediate phonological store and the articulatory rehearsal process since the earlier presented digits were likely rehearsed in instances where they are correctly remembered.

The Visuospatial Sketchpad was tested with a method similar to the method used to test the Phonological Loop. For this, the Spatial Span Test was used in order to measure the participants' Visuospatial Sketchpad (31). The Spatial Span Test presented the participants with a video in which squares in a grid are colored in and then had the color removed (31). This segment contained five questions, starting with three squares lighting up consecutively and increasing by one with each new question (Appendix B). This method tested the Visuospatial Sketchpad in the same way that the Phonological Loop was tested while still testing each of them distinctively.

Although the Phonological Loop and the Visuospatial Sketchpad were both tested using

similar tasks, Central Executive Functioning is not as concerned with memory as the other components of Working Memory. In order to test the Central Executive Functioning of participants, an adapted version of the Wisconsin Card Sorting Task was employed (32). This version provided participants with a card that consisted of three main properties: shape (squares, circles, triangles, and hexagons), color (red, blue, yellow, and green), and amount (one through four) (Appendix C). Once the participant was provided with a card, they were asked to pick one of three options that aligned with the provided card based on an unknown rule. Once these participants chose a card, they progressed to the next question which informed them as to whether or not their last answer was correct. This procedure was repeated with the rule changing every so often without the participant being alerted. This task is a staple way for psychological researchers to test a subject's Central Executive Functioning because, although it does have elements of memory, it largely tests for the attention that needs to be allocated to the Phonological Loop and the Visuospatial Sketchpad.

Alignment

The initial method for this paper envisaged an individual test being administered to each participant. While the results obtained from such individualized tests would have had greater accuracy, it would not have been feasible to administer enough tests to obtain results that were reflective of the entire population. Hence the test was converted from a paper based, to an online test. Furthermore, the online version significantly shortened the time necessary to participate, which increased the willingness of participants.

To have the results from the testing be representative of the entire population, a large group of diverse individuals was chosen consisting of students of different ages and partially varying academic levels. This ensured that the test was taken by a wide range of students so that the results could be extended to other similarly diverse populations. One concern was that different graduating classes would have different levels of knowledge; however, this issue was remedied by not using anything so complex that some high school students would not already have been exposed to it.

Analysis

Even after the test had been completed by all participants, the data obtained had little to no meaning since only the participants' answers were available. If the data was to be used and analyzed it needed to be put into a more comprehensible form. To do this, correct and incorrect answers were organized by color. Assignment of a green color meant that the answer was correct and all possible points were awarded, while a red color meant the answer was incorrect and no points were awarded. A simple system like this worked well for a majority of the questions; however, some questions' answers had varying degrees of accuracy, meaning the the simple red and green coding system no longer worked. In order to overcome this obstacle, different shades were used with lighter colors representing more correct and darker colors representing less correct answers.

Some questions, notably those for the Personal Intelligences (Appendix D and Appendix E), did not initially have correct answers. These questions, taken from the MSCEIT, could be

scored in one of two ways. The first was when responses were scored based on "the general consensus of test-takers," while the second method based correct answers on the opinion of an "expert" (29). The test used in this study used both methods in order to score these questions. In order to find "emotional experts," school counselors and therapists with degrees in psychology were tested, with the same questions as shown in Appendices F and G, and their answers were used to score the questions as being based on the opinions of experts. For scoring based on general consensus, an answer was marked correct if it had both a majority of responses and had 5 more participants choose it than the second most selected answer. If it was within five responses of the second highest, then both were marked as correct. The same applied to the expert-based scoring approach; however, an answer only required a majority of the responses to be marked as correct due to fewer responses than the regular assessment. In both systems, participants would gain more points out of the total the closer they got to the 'correct' answer(s). Additionally, a concern associated with the employment of the consensus-based approach was the reinforcement of a standard distribution or bell curve which will be discussed later in this paper. Overall, scoring the MSCEIT-based questions accurately is very important because inaccurate scoring calculations could lead to scores that do not correspond with the definitions of Gardner's Intelligences.

Once each participant's responses had been coded and marked based on how correct each response was, the responses were converted into quotients for working memory and each Intelligence using various equations (Appendix H). For the remaining duration of this paper, these scores will be referred to as Logical-Mathematical Quotient (LMQ), Verbal-Linguistic Quotient (VLQ), Interpersonal Quotient (IEQ), Intrapersonal Quotient (IAQ), Phonological Loop Quotient (PLQ), Visuospatial Quotient (VSQ), Central Executive Functioning Quotient (CEFQ), and General Working Memory Quotient (WMQ). These quotients are a way to assign a value to each part of the test. These are scored within a range from -1 to +1. Once all of the initial scoring was completed, a definitive score was calculated for WMQ and each of the personal Intelligences. In order to calculate WMQ, a participant's PLQ, VSQ, and CEFQ were averaged. The same was true for IEQ and IAQ where, for each, the scores for the general consensus approach and the expert opinion approach were averaged to create a definitive score.

Results

In total, 45 out of 45 AP Psychology students at Corvian Community School participated, which provided a response rate of 100%.

MI results

The average was found for each quotient to determine a general baseline. The quotients and their averages are as follows: LMQ had an average of 0.15, VLQ had an average of 0.47, IEQ had an average of 0.82, and IAQ had an average of 0.68. Once each of the quotients had been calculated, LMQ and VLQ were combined to create Academic Intelligence, and IEQ and IAQ were combined to create Personal Intelligence. These had average quotients of 0.31 and 0.75 respectively.

The next part of the Results that related to MI Tests is the distribution. For the histograms that

were created, Academic Intelligences were grouped into categories with a bucket size of 0.1 (shown as 10 on the graph to make it easier to read) ranging from -1 to 1 (shown as -100 to 100 on the graph to make it easier to read). However, the distribution of the Personal Intelligences had a bucket size of 0.05 since the range of scores was significantly lower than that of the Academic Intelligences. Additionally, the histograms' minimum values for the Personal Intelligences were 0 because no participants scored in the negatives for IEQ and IAQ with both scoring methods. Academic Intelligence, shown in Figure 1, was found to be a rather scattered and somewhat asymmetrical version of a normal distribution, while Personal Intelligence, shown in Figure 2, was found to be distributed in a way that was skewed to the right, with more scores that were calculated to be higher.

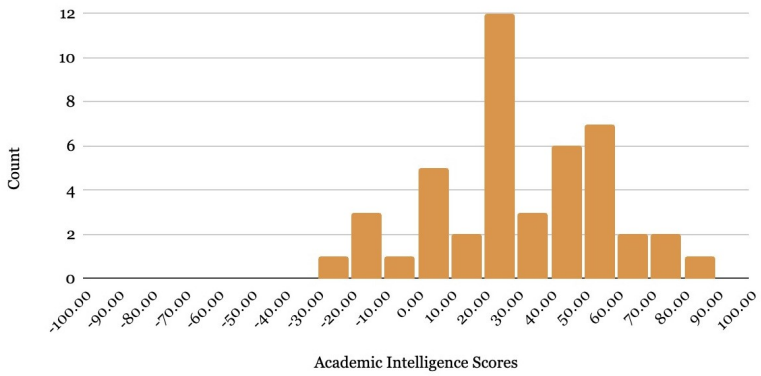

Figure 1. Academic Intelligence is distributed approximately normally.

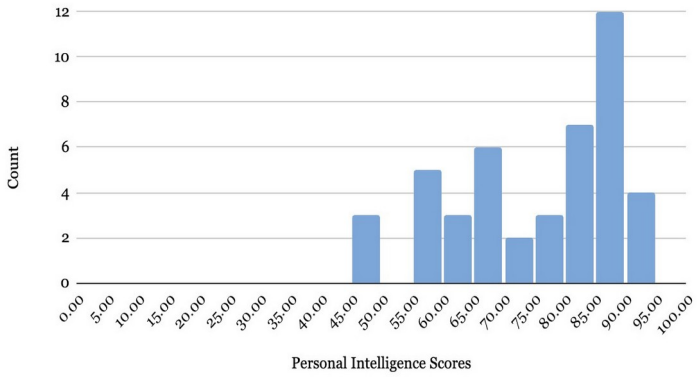

Figure 2. The distribution of Personal Intelligence is skewed to the right.

In order to observe the differences between the two methods of calculating IEQ and IAQ, histograms for each were overlaid. Figure 3 compares IEQ calculated based on general consensus and expert opinion with the lighter color representing scores based on general consensus and the darker color representing scores based on expert opinion. In Figure 4, the

same is seen to be true for each of the scoring methods for IAQ. In both cases, the scores based on expert opinion tended to be lower than when they were calculated based on the participants' general consensus.

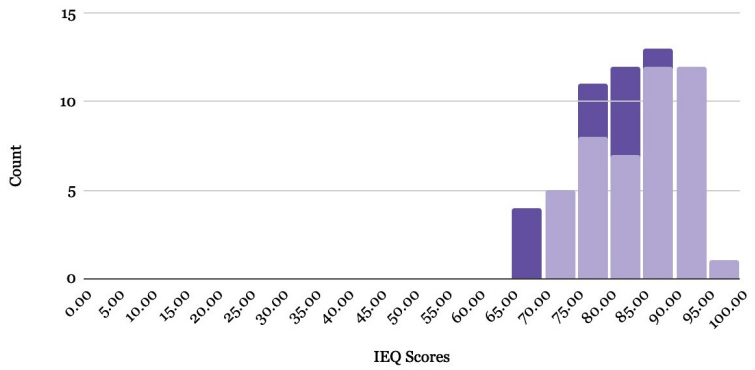

Figure 3. IEQ results, General consensus (light blue) *versus* Expert opinion (dark blue). Both methods of scoring IEQ returned generally similar scores. However, the scores were generally lower when based on Expert Opinion.

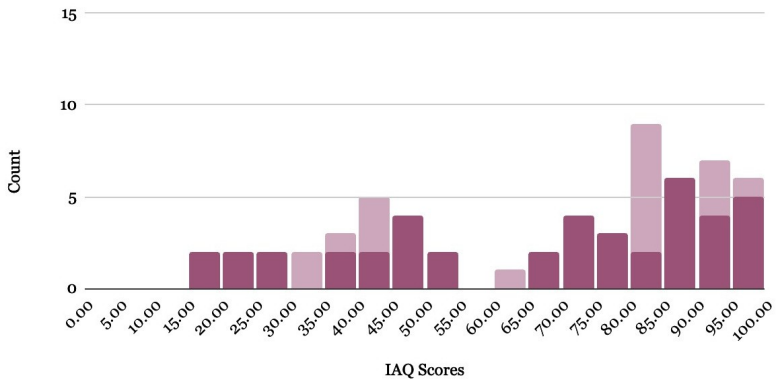

Figure 4. IAQ results, General consensus (light red) *versus* Expert opinion (dark red). Both methods of scoring IEQ returned generally similar scores. However, the scores were generally lower when based on Expert Opinion.

Working Memory results

Similar to the MI Quotients, the average was calculated for the various types of working memory. PLQ had an average of 0.48, VSQ had an average of -0.04, CEFQ had an average of -0.01, and WMQ had an average of 0.14.

WMQ was also graphed in a histogram that, like with Academic Intelligence, ranged from -100 to 100 with -100 representing -1 and +100 representing +1. Figure 5 shows that, especially compared to other distributions, WMQ has a relatively normal distribution that may be skewed slightly to the right, but not significantly.

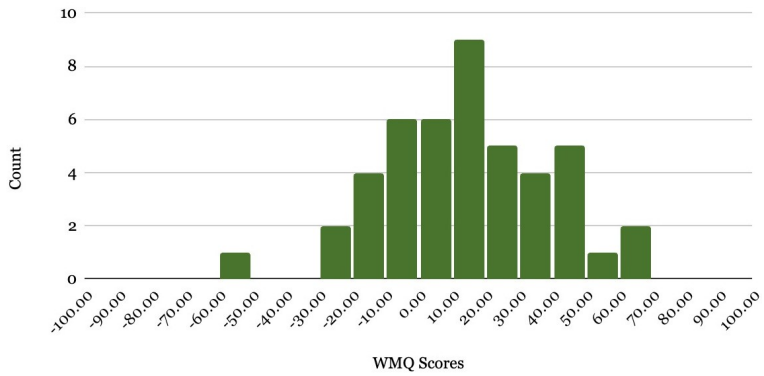

Figure 5. WMQ is distributed approximately normally.

Relationships

Once all of the MI quotients had been found, each of the MI quotients and WMQ were plotted in a scatter plot with the Intelligences on the x-axis and the working memory variants on the y-axis. The Intelligences were graphed against PLQ, VSQ, CEFQ, and WMQ. Finally, trend lines were drawn, and R^2 values, which ranged from 0 to 1, with 1 implying that the linear model could explain all the variance (100%) in the data and 0 meaning that the linear model could explain (0%) none of the variance in the data, were calculated.

The first of the working memory components was PLQ which each of the Intelligence types were graphed on a scatter plot with. All R^2 values between PLQ and the Intelligences were low, showing that none of the Intelligences as Gardner defined them were associated with the ability of a person's Phonological Loop. Notably, Academic Intelligence and Personal Intelligence, shown in Figures 6 and 7, presented with R^2 values of 0.083 and 0 respectively.

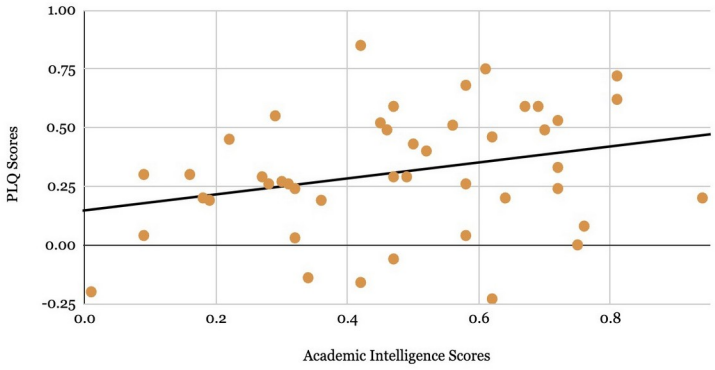

Figure 6. Academic Intelligence and PLQ are not linearly correlated (R^2<0.1)

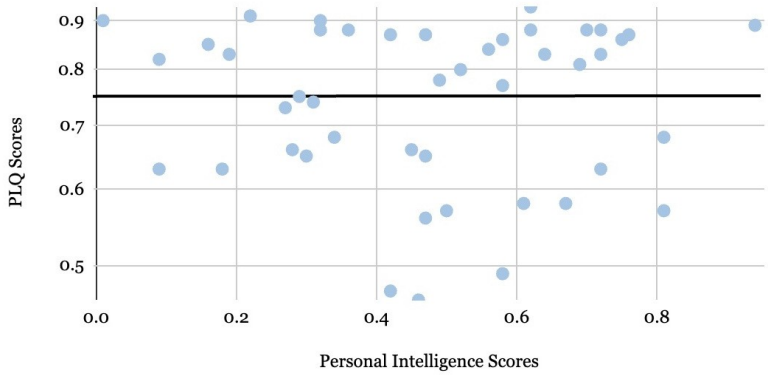

Figure 7. Personal Intelligence and PLQ are not linearly correlated (R^2<0.1)

The Intelligences were also graphed with VSQ to see if correlations were present. Similar to the PLQ correlations, these correlations were low. Academic Intelligence, which is shown in Figure 8, was found to have an $R^2 = 0.102$. The Personal Intelligence's R^2 value, depicted in Figure 9, was 0.

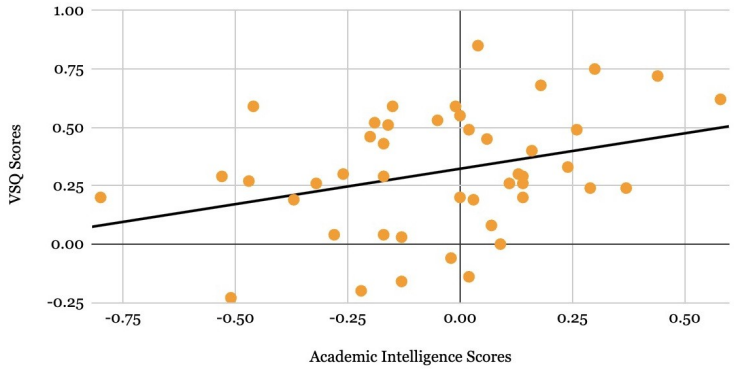

Figure 8. Academic Intelligence and VSQ are not linearly correlated (R^2<0.1)

Figure 9. Personal Intelligence and VSQ are not linearly correlated (R^2<0.1)

Similar to the VSQ and PLQ values, the CEFQ values were compared to the Intelligences to find if they were linearly correlated. As was the case with PLQ and VSQ, both Academic and Personal Intelligences presented with negligible linear correlation with CEFQ. Academic Intelligence presented with an R^2 = 0.132 in Figure 10 and Personal Intelligence, in Figure 11, with an R^2 = 0.

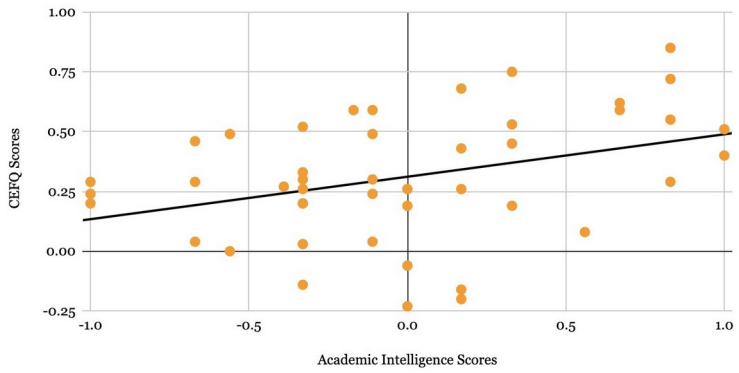

Figure 10. Academic Intelligence and CEFQ are not linearly correlated (R^2<0.1)

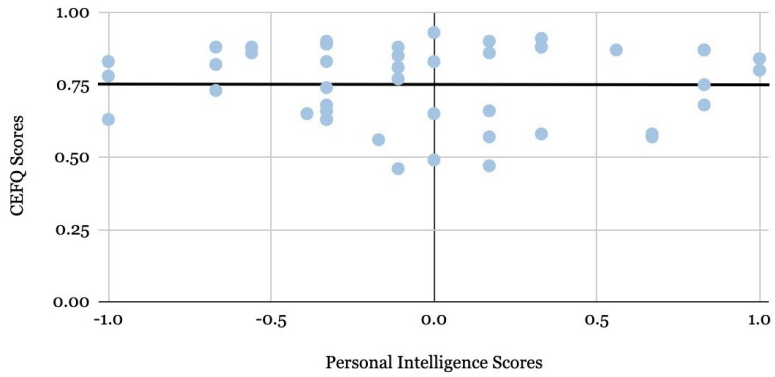

Figure 11. Personal Intelligence and CEFQ are not linearly correlated (R^2<0.1)

Finally, the correlations between WMQ and the Intelligences were exceptionally important because most literature about working memory simply refers to Working Memory, rather than the Phonological Loop, the Visuospatial Sketchpad, and the Central Executive Functioning. None of the Intelligences were found to linearly correlate with WMQ. Academic Intelligence presented with a correlation with WMQ, in Figure 12, of R^2 = 0.203. In Figure 13 Personal Intelligence, presented with an R^2 = 0 with WMQ.

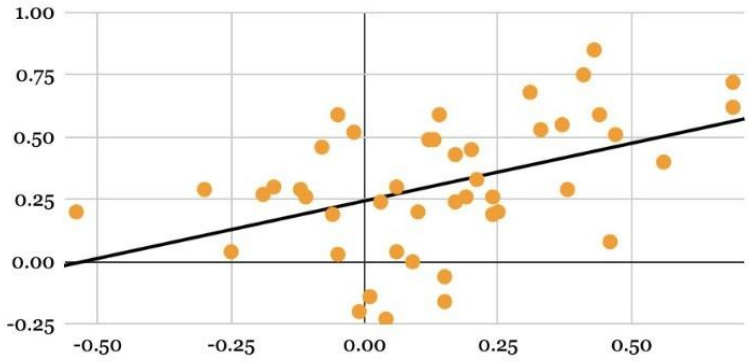

Figure 12. Academic Intelligence and WMQ are not linearly correlated (R2 < 0.3)

Figure 13. Personal Intelligence and WMQ are not linearly correlated (R^2<0.1)

Discussion

The central purpose of this research was to determine whether or not Howard Gardner's Academic and Personal Intelligences relate to the three components of Working Memory as well as to a general Working Memory capacity. Several important trends were identified throughout this study.

Distributions

Traditionally, IQ has a normal distribution (33). However, distribution can also be skewed to the left or right or it can be scattered in a somewhat random orientation. Academic Intelligence, shown in Figure 1, was distributed in a way that resembled a normal distribution that, while still being somewhat scattered, peaked between 0.2 and 0.3. On the other hand, Personal Intelligence, shown in Figure 2, was skewed to the right, with a peak between 0.85 and 0.9, meaning that, on average, participants had higher Personal Intelligence than Academic Intelligence, even if they scored worse compared to others. On the contrary, WMQ, shown in Figure 5, had a normal distribution that was centered slightly higher than 0 with a peak between 0.1 and 0.2. These distributions highlight how these factors would likely be distributed on a population scale and it puts into perspective how participants scored relative to the average since they differed between quotients.

Correlations

The heart of the research question was whether or not Academic and Personal Intelligences were correlated with Working Memory and its subtypes, using correlations to answer that question. Correlations – if found – take on importance because of a previously mentioned study that discovered that Working Memory presented with a causal relationship with Gf (23). For that reason, the presence, or the lack of a correlation could suggest that Gardner's Theory either tested for; or did not test for respectively, the same components as those present in Gf.

Overall, none of Gardner's Intelligences were found to correlate with any of the Working Memory types, including the general Working Memory capacity. Although the only scatter plots shown in this paper compare Academic and Personal Intelligence to working memory, 24 total scatter plots were graphed for every combination between tested Intelligences and Working Memory types. Among all of these correlations, the highest R^2 value = 0.203 was found between WMQ and Academic Intelligence. Although this was the highest value, the model could only explain 20% of the variance in the data. Figures 6 through 13 also do not necessarily lend themselves to confirm to other mathematical models (such as exponential, logarithmic, power etc.) since there appear to exist no trends that would be suggestive of these models.

These correlations provided evidence for the hypothesis stated in the Introduction since both Personal Intelligence and Academic Intelligence were not shown to have any significant linear correlation with different types of working memory.

Research connections

In previously conducted studies and tests, Working Memory has been shown to be a vital facet of an individual's cognitive ability. For example, in a study regarding Working Memory and cognitive ability, Working Memory was implicitly taken to be closely related to cognitive ability and even a predictor of higher-level cognitive abilities (34). This implied that a high Working Memory correlated with adept cognitive skills and abilities. This is especially important because Working Memory has been shown to have a "causal influence," rather than just being correlated with, Gf (23). In combination, these findings showed that, had this paper found a strong correlation between Gardner's Intelligences and Working Memory, a further relationship could have been postulated between Gardner's Intelligences and both cognitive ability and Gf. However, since no significant correlation was found, it is unlikely that Working Memory and MI Theory possess a causal relationship. The presence of a relationship between Gf and Working Memory, when contrasted with the apparent lack of one between MI Theory and Working Memory, further decreases the probability that MI Theory is based on the same foundations as Working Memory. This is important because the foundation that Working Memory possesses is cognitive in nature which is a vital component in almost all views of Intelligence.

Gardner's Theory has faced significant criticism in the past. The most common piece of criticism is that unlike the common definition that Intelligence necessitates, MI Theory lacks a predictive element (35). That means that the conventional definition of Intelligence requires it to be able to predict

with substantial accuracy how someone would do in similar tests. This appears to be not the case with MI Theory. Gardner even admitted it himself, saying that he wanted to challenge the normal unitary definition of Intelligence, rather than devise a theory that fit neatly within its confines (36). For these reasons, Multiple Intelligences that constitute MI theory may not fit within the definition of what is currently viewed as Intelligence; however, it should still be able to exist as an aspect that is not entirely independent of human cognition.

Implications

An important aspect of this study was to find whether the Multiple Intelligences of MI Theory were cognition dependent. A correlation with Working Memory was deemed important in order to connect these ideas as "Intelligences" rather than as talents or abilities. However, the method used in this study found that these Intelligences were cognition independent. This was because the various Intelligences did not correlate with Working Memory, an essential pillar of the cognitive abilities that define the human mind. The findings presented in this paper provide further evidence against MI Theory and in favor of the idea that Gardner's "Intelligences" may be abilities and talents, which may not constitute intrinsic Intelligence per se' but which may be influenced by the cognition-dependent current unitary definition of Intelligence.

Both Academic Intelligence and Personal Intelligence presented with low correlation with working memory as evident in their R^2 values. Since neither were found to be correlated with Working Memory, the difference between them in terms of their constituting Multiple Intelligences was non-significant. The test employed in this work was based on how Gardner himself defined Logical-Mathematical, Verbal-Linguistic, Interpersonal, and Intrapersonal Intelligence. Although ideas like mathematical problem solving may be related to Working Memory, Gardner's version of it was not, as evidenced by no correlation between Gardner's Intelligences and Working Memory. This may imply that the ideas that MI Theory is based on are not inherently incorrect, rather, the definitions, and what Gardner refers to as Intelligences are.

Limitations

Despite a Google Form being a fair platform for the study, participants were able to go back to previous pages which may have allowed them to cheat on the Working Memory segment. However, they were being proctored by a teacher to ensure they did not cheat or go back to previous sections, which significantly reduced the risk of participants cheating. Another limitation was the relatively small and limited sample study. This study might have produced more definitive results, but the limited sample size was less of an issue because the majority of the Intelligences were widely ranged with participants scoring both well and poorly. Additionally, IRB approval was not required for this study because no data or identity or personal information was collected about individual test takers. Although a hypothesis was being tested, the study was not designed to draw conclusions that were intended to be applicable and/or shared beyond the populations or situations being studied. Initially, there were concerns that participants would have to rush during the later parts of the test. Despite the concern, all participants

finished within the allotted 50-minute class time given to finish the assessment.

Perspectives

There is a lack of research regarding the Multiple Intelligences Theory. For this reason, the research in this paper and this field as a whole can be improved and expanded upon. If a researcher chooses to repeat the research in this paper, certain improvements may be recommended. Firstly, although it would be more time intensive, one-on-one tests would yield more accurate results as it would limit the number of participants cheating and would allow for more varied questions than was possible with a Google Form. Additionally, longer tests would decrease the possibility of participants scoring high based on chance.

This paper investigated if aspects of MI Theory correlated with Working Memory. It is hitherto unknown how Bodily-Kinesthetic, Musical, Naturalistic, and Spatial Intelligences relate to Working Memory. Furthermore, it is imperative that MI Theory and similar views of Intelligence are investigated in terms of whether they are cognition dependent. This study did not find a cognitive basis for the Multiple Intelligences as construed by the MI Theory. Future research in this field should continue to compare this theory with other cognitive abilities. Additionally, MI's lack of a relationship with Working Memory also is indicative of a lack of a relationship with Gf, considering that the Working Memory and Gf are closely related to one another. Since Gf is one of the most prevalent and well-tested views of Intelligence, the potential for a connection between it and MI Theory could be both interesting and beneficial to the psychological field. This study did not find that MI Intelligences correlate with Working Memory; and hence – by extension – those Intelligences would not be expected to correlate with Gf. Overall, greater connections that cognitive abilities and other types of Intelligence have with Gardner's Intelligences should be studied in order to understand whether Gardner's Theory is based on cognition, or if his Intelligences represent cognition-independent talents and abilities.

The study of Intelligence often relates to IQ, but it is nonetheless necessary that more lenses of Intelligence are viewed and their value is considered within the conversation. However, that does not mean that all of these lenses reflect the conventional way of looking at Intelligence. This is especially true when considering MI Theory because, although it seems not to be a cognition dependent theory – at least not when considering the Working Memory subset of cognition - it is one of the ways that many people think of Intelligence. Andrew Conway's findings regarding the connection between Intelligence and Working Memory largely through IQ tests highlighted the underlying cognitive function involved in both IQ and Working Memory which does not seem to be present in MI Theory, or at least not in the same capacity. There are also larger and more significant implications relating to this study such as what truly defines Intelligence and how MI Theory not only does not fit that definition but also does not work the same way as the other notable types of Intelligence when compared to Working Memory and similar cognitive abilities. A recommended course of action would be to repeat this study with adults to see if the relationships between each of the Intelligences and working memory are the same as those present in high school students.

On the other hand, similar research could build on top of cognition in comparison to MI Theory, to potentially continue to disprove the cognition dependence of MI Theory.

Conclusion

The findings in this paper demonstrate that, since the Academic and Personal Intelligence aspects of the MI theory did not linearly correlate with Working Memory, the notion that the multiple Intelligences that constitute MI Theory represent, are derived from, or are dependent on the Working Memory subset of human cognition appears unlikely and unsupported. Finally, because the question at the heart of this study aimed to determine whether Gardner's Academic and Personal Intelligences correlated with Working Memory, it was found that neither possessed a correlation with either Working Memory, or with any of its constituents; namely, the Phonological Loop, the Visuospatial Sketchpad, or the Central Executive Functioning. Based on the testing methods used in this study, it was concluded that Gardner's Theory is hence not based on cognition, rather, his Intelligences may be more representative of cognition-independent talents and abilities.

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Appendix A

Digit Span Task

Watch the video on each page only once before heading to the next question where you will be asked to recall the digits shown.

https://youtu.be/MV7YorUjHlo

Recall the digits shown in the video in the correct order.

https://youtu.be/0vhsIyFsJ2o

Recall the digits shown in the video in the correct order.

https://youtu.be/DL-31_TjSDo

Recall the digits shown in the video in the correct order.

https://youtu.be/FRxRsJ7SstU

Recall the digits shown in the video in the correct order.

https://youtu.be/fzTaO-aHrJI

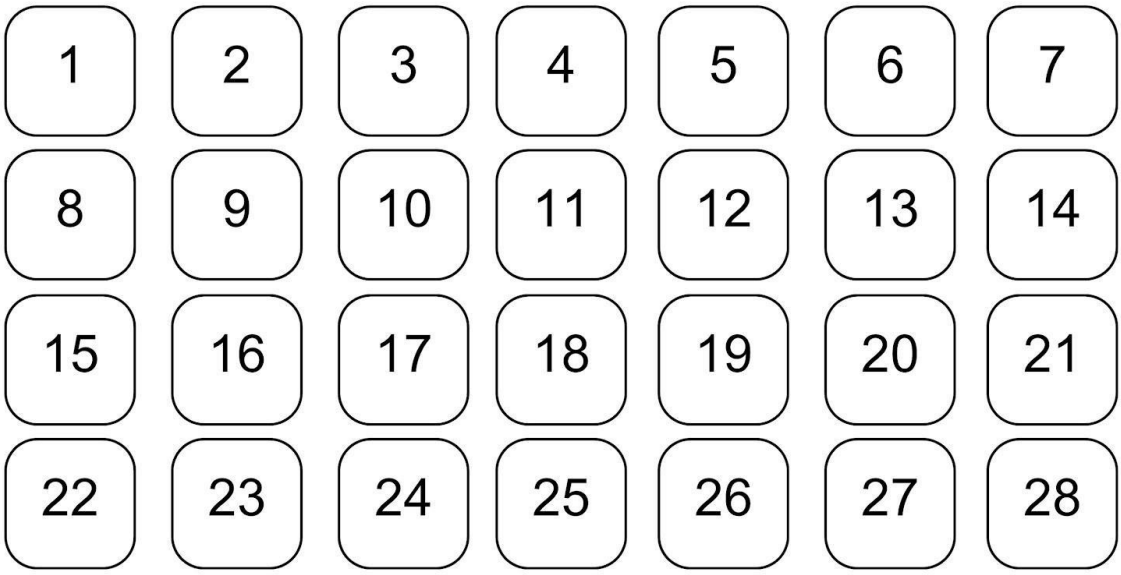
Recall the digits shown in the video in the correct order.
https://youtu.be/wiZRJPOl8rI
Recall the digits shown in the video in the correct order.
https://youtu.be/5JeWdeFlqwk
Recall the digits shown in the video in the correct order.
https://youtu.be/vWOljtFJkA0
Recall the digits shown in the video in the correct order.
https://youtu.be/UFM3ctDLOPA
Recall the digits shown in the video in the correct order.

Appendix B

Spatial Span Task

Watch the video on each page only once before heading to the next question where you will be asked to recall which squares were lit up and in what order.

Key



https://youtu.be/derN09IqErk
Recall the correct order that the boxes lit up in the video based on the numeric key.
https://youtu.be/sNFAIHKfSXw
Recall the correct order that the boxes lit up in the video based on the numeric key.
https://youtu.be/nbDAav_C0P4
Recall the correct order that the boxes lit up in the video based on the numeric key.
https://youtu.be/2XdEVuQqm-U

Recall the correct order that the boxes lit up in the video based on the numeric key.
https://youtu.be/SkgrlI_fpeM
Recall the correct order that the boxes lit up in the video based on the numeric key.

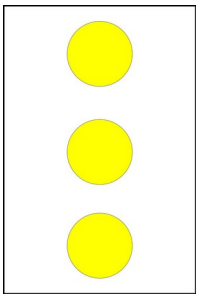
Appendix C

Wisconsin Card Sorting Task

Your task is to find out which of the following three criteria is the current sorting criteria. But sometimes the rule changes and you have to start your investigations all over again. Each of the cards that you can choose from will match one criterion from the target card. When moving to the next section you will be told whether or not you correctly chose the card that followed the same rule as the target card. Do not return to previous questions as Google Forms can verify that you did not click the "back" button or change your answers after moving to the next section.

Three criteria are: shape, color, and amount.

For example, the card shown below would be three yellow circles.



For this section, each question had a random card that possessed random qualities. There were three possible answers, each sharing one quality that were dispersed among the three possible choices. Participants were taken to different sections based on whether or not they chose the correct answer.

If participants chose the correct answer, the new section would say: CORRECT, that card follows the same rule!
If participants chose the incorrect answer, the new section would say: INCORRECT, that card does not follow the same rule.

Appendix D

Logical-Mathematical Section

Answers for all questions must be calculated in your head, without a calculator or paper. Make sure to avoid spaces, punctuation marks, or operations, as if your answer is typed incorrectly you will not gain any points.

53 + 79 =

51 - 34 =

13 * 18 =

236 ÷ 4 =

-5^2 - 2 * (-9) + 6 =

(-3)^3 - 2 + 8 ÷ (-8) =

Sandra read 5 books, Deacon read 6 books and Breanna read 7 books. One book was read by all three children, but every other book was different. How many different books did the children read?

Branson and his sister Beatrice combined their allowance of $7 each, so they could buy a movie for $12. They bought $1 containers of fruit salad with the remaining money and split the containers evenly between them. How many containers of fruit salad did they each get?

Use only the provided information to answer the questions. All information is assumed to be true in the context of the question. This information is only assumed to be true for THAT question.

You will be given one or two sentences that are true in the context of this question. You will be given another sentence and you must assess the validity based on what you have been told.

There are three possible answers. This is what they mean:
A) YES -- It must be true.
B) NO -- It cannot be true.
C) MAYBE -- It may be true or it may not be true. You weren't told enough to be certain whether it is "YES" or "NO."

Suppose you know that

> No ducks are birds.
> Nothing with large feathers is a bird.

Then would this be true?

> At least some ducks have large feathers.

A) YES

B) NO
C) MAYBE

Suppose you know that

All four-legged animals can fly.
No horses can fly.
All fast runners are four-legged animals.

Then would this be true?

No horses are fast runners.

A) YES
B) NO
C) MAYBE

Suppose you know that

All of Bill's five uncles are allowed to drive.
All people who have a license passed a driving test.
All people who are allowed to drive have a license.

Then would this be true?

At least one of Bill's uncles has not passed a driving test.

A) YES
B) NO
C) MAYBE

Suppose you know that

At least some of Mr. Johnes' students ride the bus to school.
All students who live on Route 55 own dogs.
All students who ride the bus to school live on Route 55.

Then would this be true?

None of Mr. Johnes' students own dogs.

A) YES
B) NO
C) MAYBE

Suppose you know that

At least some of Mrs. Brown's flowers are not roses.
At least some of the flowers in the flower show are not roses.

Then would this be true?

At least some of Mrs. Brown's flowers are in the flower show.

A) YES
B) NO
C) MAYBE

Appendix E

Verbal-Linguistic Section

From each list please select which options are anagrams of real english words. There are 5 correct answers for each question.

Which of these are scrambled versions of real three-letter english words?

- Pos
- Kgi
- Odt
- Pos
- Tom
- Jbu
- Uaq
- Ath
- Sdy
- Ytf
- Wer
- Enp
- Lki
- Gar
- Yoi

Which of these are scrambled versions of real four-letter english words?

- Rahi
- Sipo
- Juko
- Noir
- Ebla
- Rent
- Outh
- Waet
- Pitg
- Meoc
- Olin
- Daic
- Grto
- Ewht
- Kliu

Which of these are scrambled versions of real five-letter english words?

- Hobot
- Yhtou
- Igfuy
- Wronc
- Lkjim
- Weolb
- Goilt
- Uqotr
- Astoc
- Htsre
- Lipkt
- Hfbai
- Tihrb
- Kacsp
- Oiptr

Appendix F

Interpersonal Section

How much is each emotion expressed in the image provided?

	1 - None	2 - Little	3 - Moderate	4 - Much	5 - Extreme
Happiness	●	●	●	●	●
Fear	●	●	●	●	●
Sadness	●	●	●	●	●
Anger	●	●	●	●	●
Disgust	●	●	●	●	●
Excitement	●	●	●	●	●
Surprise	●	●	●	●	●
Anxiety	●	●	●	●	●

This section allowed participants to choose only one option in each row.

How much is each emotion expressed in the image provided?

	1 - None	2 - Little	3 - Moderate	4 - Much	5 - Extreme
Happiness	●	●	●	●	●
Fear	●	●	●	●	●
Sadness	●	●	●	●	●
Anger	●	●	●	●	●
Disgust	●	●	●	●	●
Excitement	●	●	●	●	●
Surprise	●	●	●	●	●
Anxiety	●	●	●	●	●

This section allowed participants to choose only one option in each row.

How much is each emotion expressed in the image provided?

	1 - None	2 - Little	3 - Moderate	4 - Much	5 - Extreme
Happiness	●	●	●	●	●
Fear	●	●	●	●	●
Sadness	●	●	●	●	●
Anger	●	●	●	●	●
Disgust	●	●	●	●	●
Excitement	●	●	●	●	●
Surprise	●	●	●	●	●
Anxiety	●	●	●	●	●

This section allowed participants to choose only one option in each row.

What mood(s) might be useful when meeting in-laws for the first time?

	1 - Not Useful	2 – Slightly Useful	3 – Moderately Useful	4 - Useful	5 - Very Useful
Tension	●	●	●	●	●
Surprise	●	●	●	●	●
Joy	●	●	●	●	●

This section allowed participants to choose only one option in each row.

What mood(s) might be useful when composing an inspiring military march?

	1 - Not Useful	2 – Slightly Useful	3 – Moderately Useful	4 - Useful	5 - Very Useful
Anger	●	●	●	●	●
Excitement	●	●	●	●	●
Frustration	●	●	●	●	●

This section allowed participants to choose only one option in each row.

Appendix G

Intrapersonal Section

Answer each question to the best of your ability.

You feel anxious and become a bit stressed when thinking about all the work you have to do. How would you feel if your supervisor gives you an additional project?

A) Overwhelmed

B) Depressed
C) Ashamed
D) Self-Conscious
E) Jittery

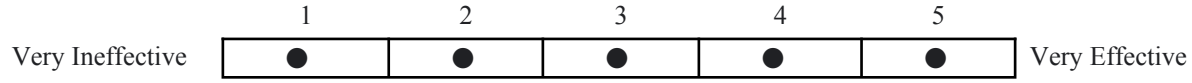
You are usually quite happy at work and at home and feel that you and your co-workers are paid and treated fairly. Today everyone in your unit received a modest pay increase as part of corporate wide adjustments in salary. How would you feel?

A) Surprised and Shocked
B) Peaceful and Quiet
C) Content and Elated
D) Humbled and Guilty
E) Proud and Dominant

BASE YOUR ANSWERS ON THE SITUATION BELOW

You wake up feeling pretty well. You slept well, feel well rested, and have no particular cares or concerns. How will each action help preserve your mood?

You get up and enjoy the rest of the day.



You enjoy the feeling and decide to think about it and appreciate everything that is going well for you.

You decide to ignore the feeling since it won't last anyway.

You use the feeling to call a friend that has been upset and try to cheer them up.

Appendix H

Equations

The variables Qx(meaning question x) and Sx(meaning section x) refer to the number of points received on that question or in that section. The variable x#A refers to the total number of answered questions in section x of the CEFQ test. The variable x#C refers to the total number of correct answers in section x of the CEFQ test.

$$PLQ = \{ \frac{2\left(\frac{Q1}{4}+\frac{Q2}{5}+\frac{Q3}{6}+\frac{Q4}{4}+\frac{Q5}{5}+\frac{Q6}{6}+\frac{Q7}{8}+\frac{Q8}{8}+\frac{Q9}{8}\right)}{9} \} -1$$

$$VSQ = \{ \frac{2\left(\frac{Q1}{3}+\frac{Q2}{4}+\frac{Q3}{5}+\frac{Q4}{6}+\frac{Q5}{7}\right)}{5} \} -1$$

$$CEFQ = \{ \frac{2(3A)}{3} \} -1$$

$$WMQ = \frac{PLQ+VSQ+CEFQ}{3}$$

$$LMQ = \{ \frac{S1}{8}+\frac{S2}{5} \} -1$$

$$VLQ = \{ \frac{\frac{Q1}{5}+\frac{Q2}{5}+\frac{Q3}{5}}{3}+\frac{S2}{4} \} -1$$

$$\text{Academic intelligence} = \frac{LMQ+VLQ}{2}$$

$$IEQ = \{[\sum_{1}^{24} Q\,] /(24x5)\} + \{[\sum_{25}^{30} Q] /(6x5)\} -1$$

$$IAQ = \{ \frac{S1}{2}+\frac{\frac{Q1}{5}+\frac{Q2}{5}+\frac{Q3}{5}+\frac{Q4}{5}}{4} \} -1$$

$$\text{Personal intelligence} = \frac{IEQ+IAQ}{2}$$