Continuing the Search: Working Memory Measures as a Predictor of Immediate and Long-Term Performance

By

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ABSTRACT

In this study, the effects of working memory were correlated with scores on a learning performance measure taken both immediately after training and three weeks post training in an academic astronomy lab experiment. The reasoning for this research was based on findings by Bosco et al. (2015) which indicated strength for working memory as a predictor of performance nearly on par with that of the often-used cognitive ability tests. The present study found that the working memory measures and performance on an immediate learning-oriented posttest were correlated. However, further analysis through a linear model indicated that working memory did not account for any statistically significant variance in performance over time. These findings could be due to the limitations of our research study given that data were pulled from a larger grant research project what was not solely designed to compare working memory and performance. More research should be done in this area given the positive findings in other research in this area.

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CHAPTER 1: LITERATURE REVIEW

Introduction

For over a century, organizations have been relying on a highly predictive and highly biased selection tool: cognitive ability tests. Cognitive ability tests such as the Wonderlic Personnel Test and the Armed Services Vocational Aptitude Battery (ASVAB Enlistment Testing Program, 2020), tend to show large biases in favor of white test takers (Bosco et al, 2015; Ployhart & Holtz, 2008; Roth et al., 2001). The battle between the high predictive validity of cognitive ability tests on employee performance and the drastic adverse impact that is presented by those same tests has created what has been termed a diversity-validity dilemma (Bosco et al., 2015; Ployhart & Holtz, 2008).

In an initial attempt to discover a less-biased alternative to using cognitive ability tests for selection purposes, Bosco et al. (2015) completed a study using working memory tests as one alternative solution. Through the findings of their study, Bosco et al. (2015) indicated that tests of executive attention, a factor of working memory, predicted performance at nearly the same level as cognitive ability tests but, with less racial bias. Further, Chan et al. (2021) argue that executive functions (EF) may explain performance beyond general intelligence (g) because g is only useful when individuals apply the right amount of executive attention (EA) and working memory (WM) to the situation in which g is required. They suggest this is due to the individual using working memory and its subcomponent, executive attention, to efficiently block out irrelevant information such as inaccurate intuitions. The purpose of the current study is to further this area of research by assessing working memory as a predicter of initial performance as well as sustained performance over time on a measure of learning after a presented training in an academic setting. Given that working memory could be useful for work and academic settings, the present study focuses on academic learning that occurred in an augmented reality astronomy lab at a four-year university. The learning performance was measured at two separate times, once immediately after the astronomy training and once again three weeks post training.

It may also be noted that many of our measures of IQ, such as the Wechsler Adult Intelligence Scale (WAIS) used in personnel selection, also contain sub measures of working memory, indicating that working memory has long been viewed as a critical factor of measuring intelligence (Wechsler, 1981). Despite its use in IQ testing, working memory has not yet been widely explored as a cognitive assessment of performance because it is not reflected or used in the cognitive ability test measures most often used. This indicates further support for assessing working memory as a potential predicter of performance. To further explore this option, we first must understand what working memory is and how it functions.

Executive Functioning

To better understand working memory, and why it has the potential to predict performance at a similar level as cognitive ability tests, it is helpful to understand the larger concept of executive functioning (EF). EF is a cognitive tool that facilitates the use of general intelligence (g) but also has the potential to impact other factors, such as decision making, emotional regulation, and problem-solving ability, especially in situations that are ambiguous or time-constrained (Chan et al., 2021; McCabe et al., 2010). It should be noted that EF research and definitions are often conflicted in whether to define EF as one function or one function with multiple sub-functions (McCabe et al., 2010). Chan et al. (2021) describe the three distinct, but often highly interdependent, core facets or functions of EF to include inhibition, working memory, and shifting, and these concepts, though termed differently in various areas of research, have been found to be generally conceptually stable (Bosco et al., 2015; Diamond, 2013; Burgoyne et al., 2021; McCabe et al., 2010).

In his article, McCabe et al. (2010) described that EF plays a role in performance beyond that which is explained by general intelligence due to the necessity of an individual's use of attention control, which occurs through the EF processes, on accurately applying general intelligence (which is what is most often measured by cognitive ability tests). The extent to which individuals have and use their EF processes is argued to be critical for how well people perform on cognitive tasks, including judgment and decision making, because these cognitive tasks require the capacity to control attention and flexibly manipulate information (Chan et al., 2021). Working memory is often described as the combination of short-term memory (STM) and executive attention (Engle, 2002; Kane et al., 2003). Studies comparing individual differences in working memory capacity and performance on cognitive tasks indicate that individual differences do exist and were found to impact performance where individuals with higher working memory capacity did better than those with lower working memory capacity on intentional learning tasks (Unsworth et al., 2005). These findings support the hypotheses that will be used for the current study.

Working Memory

Working memory (WM) is an executive function that facilitates the human ability to hold a stimulus or information in our minds and to manipulate that information (Aben et al., 2012; Diamond, 2013). The most influential model of WM is the Baddeley & Hitch (1974) model in which WM is comprised of three facets including the phonological loop, the visuospatial sketchpad, and the central executive. Working memory is of particular interest as it is often defined as an individual's ability to hold information in mind while manipulating that information using both information from long-term memory as well as new stimuli (Chan et al., 2021). Though the definitions of WM are vast and not always fully congruent, the idea that it involves both memory and attention is consistent (Aben et al., 2012; Engle, 2002; Kane et al., 2003). In their initial study, Bosco et al. (2015) looked at WM, and more specifically executive attention (EA), as an alternative to cognitive ability tests for using cognitive tests to predict performance. The goal was, and remains to be, to find a cognitive test that predicts performance as well as cognitive ability tests with less reliance on crystalized intelligence to mitigate the effects of adverse impact in personnel selection (Burgoyne et al., 2021).

It should be noted that components of WM are guised under several different terms in the research, spanning from cognitive to behavioral to organizational psychology. For example, what Baddeley and Hitch (1974) termed as the ‘central executive’ is the same concept as what has otherwise been termed attention control and executive attention (Bosco et al., 2015; Engle, 2002; Unsworth et al., 2021). From this point, we will refer to this concept as executive attention (EA). To clarify the distinctions between working memory (WM), short term memory (STM), and executive attention (EA), refer to the Kane et al. (2003) conceptualization of WM = STM + EA. In this conceptualization, WM uses STM to hold and maintain information and uses EA to manipulate that information (Diamond, 2013; Kane et al., 2003; McCabe et al., 2010).

To further explore why WM is a potentially valid alternative predictor of performance, it is beneficial to view the relationships that make up the WM. Engle et al. (1999) looked at the relationship between WM, STM, and general fluid intelligence (gF). Their findings indicated that when the common variance between WM and STM is factored out (remember that STM is a component of WM and therefore it makes sense that there would be some mutual variance explained between the two), correlations between STM and gF disappear, but the correlation between WM and gF remains (Engle, 2002; Engle et al., 1999). Engle (2002) further suggested that, logically, it could be understood that the remaining variance was due to the EA component of WM. The implications of these findings is that WM is correlated to gF due to EA (Engle, 2002; Engle et al. 1999). WM and EA being correlated with gF is important because it provides support and a potential explanation for why WM capacity is correlated with performance on other cognitive-performance tasks (Engle, 2002; Unsworth et al., 2005). Kane et al. (2003) further argue that EA is a distinct construct from WM because of the predictive nature of the tasks used to study the constructs. They postulate that though WM tasks often predict performance on EA tasks, EA tasks do not predict WM tasks, suggesting that EA acts as only part of what makes up WM (Kane et al., 2003). Executive Attention will be the primary facet of working memory used in this paper and will be discussed in further detail in the next section.

Executive Attention

Unsworth et al. (2021) define attention control, otherwise known as EA, as the “set of processes that allow us to focus selectively and actively maintain task-relevant information in order to guide thought and action in the presence of internally or externally distracting information” (pg. 1332). In research, EA is often comprised of mechanisms and processes for updating and manipulating information being stored in STM and inhibiting distractions (Bosco, 2015; Diamond, 2013; Unsworth et al., 2005; Unsworth et al., 2021). Why does this matter? Well, given the current trends of near-constant distraction due to technology (Barber et al., 2019) and conditions of working virtually from home brought on by the COVID-19 pandemic amongst an array of other changes to the world of work, an individual’s level of EA could be crucial for workplace performance (Bosco, 2015; Kane et al., 2003). Thus, in addition to potentially decreasing testing biases, research to discover the potential of EA as a predictor of job performance can add value to our selection methods (Bosco et al., 2015).

Inhibition and interference are two EA processes that are frequently brought up in the attention literature and they refer to an individual's ability to ignore or forget old irrelevant information or stimuli and to notice and use new relevant information or stimuli respectively (Diamond, 2013; Unsworth et al., 2021). These capacities have the potential to impact performance because they affect other cognitive processes such as decision making, self-regulation, and perspective-taking (Chan et al., 2021). For example, if an individual is progressing towards a goal, but new information arises that informs them that the goal needs to be changed or abandoned, an individual with higher EA functioning would theoretically be able to make those adjustments more swiftly and effectively (Chan et al., 2021; McCabe et al., 2010).

Individual differences in performance based on WM, more specifically EA, form the basis for the current study. Researchers studying individual differences in EA have found that an individual's level of working memory capacity will affect their ability to maintain a task goal in a given situation where those with high levels of working memory capacity were better able to mentally maintain and use the task goal and perform the task correctly more often than those with low WMC (Kane et al., 2003). In a study examining the relationship between the measure of working memory, working memory capacity, and its effect on sequential learning, it was found that WMC was significantly correlated with higher-order cognition (Unsworth et al., 2005). In other words, Unsworth et al. (2005) found that individual differences in WMC predicted performance on intentional learning tasks where individuals with higher WMC performed better than individuals with lower WMC. Intentional learning tasks were defined as tasks that required the use of EA and differences were assumed to exist due in part to the extent to which an individual has the ability to effectively use EA (Unsworth et al., 2005). Based on this research and the initial Bosco et al. (2015) findings, we hypothesize that individuals who score higher on working memory measures will perform better than individuals who score lower on working memory measures.

The present study analyzed individual differences in performance in an academic setting and more specifically in a grant-based augmented reality (AR) astronomy lab. In this research, participants in the experimental group were asked in a premeasure to complete four working memory tests, provided an AR astronomy training, and asked to complete a quiz covering information learned in the training immediately post training and again after a three-week time laps. Control condition participants were also asked to complete the same working memory tests and performance tests but were provided with text-only astronomy training (as opposed to the AR training). As these experimental conditions could act as a confound to our findings, we analyzed data for the control group and the experimental groups separately.

Hypothesis 1: Individuals who score higher on working memory measures will perform better on the AR lab posttest than individuals who score lower on working memory measures.

Hypothesis 2: Individuals who score higher on working memory measures will perform better on the AR lab posttest than individuals with lower working memory scores over time.

CHAPTER 2: METHODOLOGY

Participants

Participants were undergraduate students from the psychology subject pool at a four-year university. In the collection of data, no demographical data were collected on participants, however all participants were college students enrolled in an psychology course at the time of participation. Data were collected from a final sample of 107 participants on the immediate posttest data collection and 72 participants on the 3-week delayed posttest data collection.

Procedure

Data were collected as part of a larger grant research project. Students were provided with course credit for participation. Students received three credits for completing the first section of the research which included the pretest, experimental training, and posttest. Participants who completed the delayed posttest were provided with one additional credit. Students were asked to come into a lab setting to complete the first stages of the research which entailed a pretest on the material to be trained, training in either an experimental or control condition, and a post-test on the covered material. Three weeks later, the delayed posttest was administered online, and students were not required to take the delayed posttest in the lab. Working memory measures were administered to all participants as a part of a larger set of pre-test measures. Students were directed to the PsyToolkit webpage where they were to complete four tests of working memory: the digit span, reverse digit span, Corsi, and backwards Corsi tasks.

Measures

Performance. Performance was measured through a test to assess learning. Specifically, this study used pre-, post-, and delayed posttests, each consisting of eight items, which collected information on the students' knowledge of basic astronomy. Students were provided up to five multiple choice response options for each item. All three tests were identical and administered via Qualtrics surveying software. Items included questions such as "A sidereal month is the time it takes for the Moon to:", "For the picture below, how many days are left before the next New Moon?", and "Why isn't there a solar eclipse every month?". Overall performance scores were created by coding responses as correct (1) or incorrect (0) and summing across all eight items for a total of up to eight points.

Working Memory. Participants completed the Digit Span, Reverse Digit Span, Corsi task and backwards Corsi task (Corsi, 1972; Wechsler, 2008). All tasks were administered via online and un-proctored tests on PsyToolKit.org (Stoet, 2010; Stoet, 2017).

Digit Span. This working memory measure was administered via PsyToolkit software. In this test, participants were presented with a series of numbers that flashed on the screen. After several numbers were presented, a textbox appeared on screen and participants needed to recall the numbers presented, in the order in which they were presented (e.g., if 3, 4, 7, and 4 were presented, participants should enter 3474 in the rectangle). Instructions were presented and participants were given three trials before the task officially began.

The task ended when participants incorrectly recalled the list of digits twice in a row.

Reverse Digit Span. The only difference between the digit span task and the reverse digit span task is that participants were instructed to type the presented digits in the textbox in backwards order from which they were presented. For example, if 3, 5, 6, and 2 are the digits presented, participants should type 2, 6, 5, and 3 into the response rectangle to be correct. Instructions were presented and participants were given three trials before the task officially began. The task ended when participants incorrectly recalled the list of digits twice in a row.

Corsi task. In this task, participants were presented with nine pink blocks which were displayed scattered around an otherwise black screen. When the test began, the blocks flashed yellow in sequence. Once the participant was shown a sequence and heard "go", they needed to click the boxes in the same sequence that was presented. As the test goes on, the sequences get longer. Instructions were presented and participants were given three trials before the task officially began. The task ended when participants incorrectly recalled two sequences in a row.

Backwards Corsi task. The only difference between the Corsi task and the backward Corsi task is that participants were instructed to click the blocks in reverse order from which they were presented. Instructions were presented and participants were given three trials before the task officially began. The task ended when participants incorrectly recalled two sequences in a row.

CHAPTER 3: RESULTS

Participants who did only completed partial or did not complete any of the predictive measures were deleted from the data set. The remaining sample (N = 179) was analyzed using Jamovi statistical software (The Jamovi Project, 2022). It should be noted that participants were divided into two groups, an experimental group (N = 120) and a control group (N = 59) and data were analyzed separately in order to mitigate the type of astronomy training, the experimental condition, as a confound in the present study. Descriptive statistics are presented in Table 1.

Table 1

Descriptive Statistics

	Group	N	Mean	Standard Deviation	Min	Max
Performance	1	59	3.76	1.32	1	7
	2	120	4.48	1.37	2	7
Digit Span	1	59	5.24	1.16	3	8
	2	120	5.63	1.18	3	8
Backward Digit Span	1	59	4.46	1.37	2	9
	2	120	4.41	1.18	2	7
Corsi	1	59	6.03	1.31	3	9
	2	120	5.63	1.41	0	9
Backward Corsi	1	59	4.97	1.70	0	8
	2	120	5.21	1.80	0	8

Note. Group 1 represents participants who were in the control group, receiving astronomy learning materials only. Group 2 represents participants who were in the experimental group, participating in AR learning.

Correlational Analysis

A correlational analysis was conducted to analyze the relationships between our performance and working memory. Specifically, working memory was correlated with the immediate posttest performance measure and then the 3-week posttest performance measure separately. Aside from significant correlations between the working memory measures themselves, performance on the initial posttest was significantly correlated with the Backward Digit Span ($r = 0.16$, $p = 0.03$) and the Backward Corsi ($r = 0.15$, $p = 0.04$). The positive direction of these findings suggest support for hypothesis 1, that individuals who score higher on working memory measures also scored higher on the performance initial performance measure. These findings suggested initial support for the potential of these working memory tests to predict performance, these findings were further explored using a linear model which will be discussed later.

It should also be noted, given the broader context of the AR research study, that there was a statistically significant correlation between group membership (i.e., whether individuals were in the experimental or control astronomy learning group), and performance ($r = 0.24$, $p < .001$). Though this may have implications for other pieces of this research, it will not be discussed within the context of the current paper. The full correlation matrix for the immediate posttest performance measure can be viewed in Table 2.

Table 2

Pearson Correlation Coefficients for Initial Performance Posttest

	1	2	3	4	5	6
1. Overall Performance Score	-- --					
2. Digit Span	0.14	-- --				
3. Backward Digit Span	0.16*	0.30***	-- --			
4. Corsi	0.11	-0.05	0.18*	-- --		
5. Backward Corsi	0.15*	0.06	0.18*	0.21**	-- --	
6. Group	0.24***	0.16*	-0.02	-0.14	0.06	-- --

*Correlation is significant at the .05 level.
***Correlation is significant at the <.001 level.

Performance on the 3-week posttest was not significantly correlated with any of the working memory measures used in this study. It may again be noted that there was a statistically significant correlation between performance and group membership (r = 0.39, $p < .001$). The full correlation matrix for the 3-weeks posttest performance measure can be viewed in Table 3.

Table 3

Pearson Correlation Coefficients for 3-Week Performance Posttest

	1	2	3	4	5	6
1. Overall Performance Score	-- --					
2. Digit Span	0.06	-- --				
3. Backward Digit Span	0.11	0.33**	-- --			
4. Corsi	0.17	0.00	0.19	-- --		
5. Backward Corsi	0.09	0.05	0.15	0.25*	-- --	
6. Group	0.39***	0.11	0.01	-0.09	0.05	-- --

*Correlation is significant at the .05 level.

***Correlation is significant at the <.001 level.

Mixed Linear Model

To analyze our second hypothesis, we completed the planned linear mixed model analysis to assess whether the WM measures predicted test performance over time. The model included all performance and working memory tests as well as a Time variable (immediate and 3-week posttest) to assess whether performance over time was predicted by the working memory measures. Group membership remained separate variables in order to control for the potential confound of experimental condition.

The results of our linear mixed model analysis indicated the WM measures did not have significant unique effects on performance in the AR labs in which this study was conducted. In support of the larger AR grant lab context, it can be noted that we did find a significant effect between group (whether the can be noted that we did find a significant effect between group (whether the participant was in the experimental or control condition) and performance over time. More specifically, individuals in the control condition performed statistically significantly worse overtime whereas individuals in the experimental condition had a nonsignificant positive improvement over time. The parameter estimates for the model assessing working memory and performance over time can be viewed in Table 4.

Table 4

Fixed Effects Parameter Estimates for Performance and Working Memory

				95% Confidence Interval				
Name	Effect	Estimate	SE	Lower	Upper	df	t	p
(Intercept)	(Intercept)	4.72	0.42	3.89	5.55	96.1	11.18	<.001***
Time	Time	-0.25	0.17	-0.59	0.08	86.7	-1.48	0.14
Digit Span	Digit Span	0.09	0.10	-0.11	0.30	100.4	0.92	0.36
Backward Digit Span	Backward Digit Span	0.14	0.10	-0.06	0.33	96.3	1.35	0.18
Corsi	Corsi	0.08	0.09	-0.09	0.25	98.3	0.91	0.36
Backward Corsi	Backward Corsi	0.08	0.07	-0.05	0.21	102.9	1.14	0.26
Group	Group	-1.35	0.85	-3.01	0.32	96.9	-1.59	0.12
Time* Group	Time* Group	0.87	0.34	0.20	1.54	86.6	2.55	0.01**

CHAPTER 4: DISCUSSION

The results of these analysis lead the researchers to conclude that there were correlations among working memory measures and the initial posttest performance measure which suggests support for hypothesis 1. However, the lack of significant findings in the 3-week posttest performance measure and the linear model analysis indicates no support for hypothesis two.

There are a few reasons that we may have only found insignificant results despite the initially promising outlook for working memory as a predictor of performance. For example, working memory and more specifically executive control held the most potential for predicting performance because they help individuals inhibit the negative effects of distractions while performing, therefore potentially allowing individuals to perform better on tasks. However, our study did not use performance measures that occurred in a setting or involved the need for intense distraction inhibition or complex memory tasks. Therefore, there is potential that our performance measure did not allow for differences in working memory capacity to be identified. Though our findings cannot support working memory as a predictor of performance in the context of this research, findings from other, similar research have been positive. Therefore, more research ought to be done in this area and should include more workplace-relevant situations, given the finding of larger studies such as the Bosco et al. (2015) research.

Conclusions

Given the results of this study, using working memory as a predictor of performance in an academic or learned-information context may not be beneficial. However, more research should be done with working memory as a predictor of performance on tasks that involve the use of executive attention (the ability to control attention and inhibit distraction) such as work samples or situational judgment tests that involve time pressure. Lastly, this research serves to inform the larger data collection project as to whether to continue in the current direction or pivot.

REFERENCES

Aben, B., Stapert, S., & Blokland, A. (2012). About the distinction between working memory and short-term memory. *Frontiers in Psychology*, *3*(AUG). https://doi.org/10.3389/fpsyg.2012.00301

ASVAB Enlistment Testing Program. (2020). *What is ASVAB?*. August 13. Retrieved July 30, 2022, from https://www.officialasvab.com/

Baddeley, A. D., & Hitch, G. (1974). Working memory. *The Psychology of Learning and Motivation*, *8*, 47–89. https://doi.org/10.1016/S0079-7421(08)60452-1

Barber, L. K., Conlin, A. L., & Santuzzi, A. M. (2019). Workplace telepressure and work–life balance outcomes: The role of work recovery experiences. *Stress and Health*, *35*(3), 350–362. https://doi.org/10.1002/smi.2864

Bosco, F., Allen, D. G., & Singh, K. (2015). Executive attention: An alternative perspective on general mental ability, performance, and subgroup differences. *Personnel Psychology*, *68*(4). https://doi.org/10.1111/peps.12099

Burgoyne, A. P., Mashburn, C. A., & Engle, R. W. (2021). Reducing adverse impact in high-stakes testing. *Intelligence*, *87*, 101561. https://doi.org/10.1016/j.intell.2021.101561

Chan, T., Wang, I., & Ybarra, O. (2021). Leading and managing the workplace: The role of executive functions. *Academy of Management Perspectives*, *35*(1), 142–164. https://doi.org/10.5465/AMP.2017.0215

Corsi, P. M. (1972). Human memory and the medial temporal region of the brain. McGill University.

Diamond, A. (2013). Executive functions. *Annual Review of Psychology*, *64*(1), 135–168. https://doi.org/10.1146/annurev-psych-113011-143750

Engle, R. (2002). Working memory capacity as executive attention. *Current Directions in Psychological Science*, *11*(1), 19–23.

Engle, R., Laughlin, J., Tuholski, S., & Conway, A. (1999). Working memory, short-term memory, and general fluid intelligence: A latent-variable approach. *Journal of Experimental Psychology: General*, *128*(3), 309–331.

Kane, M. J., & Engle, R. W. (2003). Working-memory capacity and the control of attention: the contributions of goal neglect, response competition, and task set to stroop interference. *Journal of Experimental Psychology: General*, *132*(1), 47–70. https://doi.org/10.1037/0096-3445.132.1.47

McCabe, D. P., Roediger, H. L., McDaniel, M. A., Balota, D. A., & Hambrick, D. Z. (2010). The relationship between working memory capacity and executive functioning: Evidence for a common executive attention construct. *Neuropsychology*, *24*(2). https://doi.org/10.1037/a0017619

Ployhart, R. E., & Holtz, B. C. (2008). The diversity-validity dilemma: Strategies for reducing racioethnic and sex subgroup differences and adverse impact in selection. *Personnel Psychology*, *61*(1). https://doi.org/10.1111/j.1744-6570.2008.00109.x

R Core Team (2021). *R: A Language and environment for statistical computing*.

(Version 4.1) [Computer software]. Retrieved from https://cran.r-project.org. (R packages retrieved from MRAN snapshot 2022-01-01).

Roth, P. L., Bevier, C. A., Bobko, P., Switzer Iii, F. S., & Tyler, P. (2001). Ethnic group differences in cognitive ability in employment and educational settings: A meta-analysis. *Personnel Psychology*, 54, 297–330. https://doi.org/10.1111/j.1744-6570.2001.tb00094.x

Stoet, G. (2010). PsyToolkit - A software package for programming psychological experiments using Linux. *Behavior Research Methods, 42(4)*, 1096-1104.

Stoet, G. (2017). PsyToolkit: A novel web-based method for running online questionnaires and reaction-time experiments. *Teaching of Psychology, 44(1)*, 24-31.

The jamovi project (2022). *jamovi*. (Version 2.3) [Computer Software]. Retrieved from https://www.jamovi.org.

Unsworth, N., & Engle, R. (2005). Individual differences in working memory capacity and learning: Evidence from the serial reaction time task. *Memory & Cognition*, *33*(2), 213–220. https://doi.org/10.3758/BF03195310

Unsworth, N., Miller, A., & Robinson, M. (2021). Are individual differences in attention control related to working memory capacity? A latent variable mega-analysis. *Journal of Experimental Psychology: General*, *150*(7), 1332–1357. https://doi.org/10.1037/xge0001000.supp

Wechsler, David, 1896-1981. (1981). WAIS-R : Wechsler adult intelligence scale-revised. New York, N.Y. :Psychological Corporation.

Wechsler, D. (2008). Wechsler Adult Intelligence Scale-Fourth Edition: Administration and scoring manual. San Antonio, TXNCS Pearson.

APPENDIX: ***Performance Measure***

1. The moon goes through its phases because:

    Correct Answer: The Moon is an orbiting, spherical object.

2. Why isn't there a solar eclipse at every month?

    Correct Answer: The orbit of the Moon is not perfectly aligned with the Earth's orbit.

3. Would the moons of Mars go through phases like Earth's moon?

    Correct Answer: Yes

4. For the picture below, how many days are left before the next New Moon.

    Correct Answer: About 3 days

5. A sidereal month is the time it takes for the Moon to:

    Correct Answer: Be aligned with the same background stars during its orbit.

6. What is the name of the phase of the moon in this picture?

    Correct Answer: First Quarter

7. Imagine you living on the moon. When you look up at the sky, you see Earth and the Sun are both above the horizon. Over the next four weeks, you will see:

    Correct Answer: The sun will rise and set. the earth will remain in the same place in the sky.