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The Impact of Sleep, Mood, Physical Activity, and Study Time on Memory Retention.

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ABSTRACT

In this paper, we aim to discover what factors influence memory retention, and how to improve our ability to retain relevant information to recall at a later time. Previous research has predicted levels of memory retention by variables such as the amount of sleep a person has each night, the level of anxiety-depression a person experiences, the level of physical activity someone does each day, and study duration, frequency, and spacing. In our first (correlational) study, we tested the strength of these relationships by examining naturalistic daily changes in their variables longitudinally over one week. We measured sleep by tracking the number of minutes of sleep during each night, and the level of anxiety-depression by tracking heart rate, urine and subjective mood of anxiety-depression. We recorded physical activity by tracking how much exercise we did throughout the day and the intensity of the exercise on a 1-9 scale. For studying we tracked the overall amount of time spent studying, the number of times studying took place, how long each study session was, and how long the space was in between study sessions. Memory retention was tested by our ability to remember at the end of the day a set of 20 randomized words given in the morning. Based on the strength of correlation found between study time and memory retention, we then conducted a second (experimental) study to test for a causal relationship between these two variables. Over eight days we assigned participants on alternating days to have either 3 separate 5-minute study sessions or just 1 single study session and measured the effect this had upon memory and anxiety-depression. Data pooled across participants in our correlational study showed significant correlations of memory retention with anxiety-depression subjective measurements, overall study time, study session frequency, duration, and spacing, but not with sleep amount, heart rate, time spent urinating, nor with physical activity amount and intensity. Data from our experimental study showed that increasing study time caused an enhancement of memory retention, which could not be accounted for by changes in anxiety-depression. Based on our experimental results, we recommend that in order to improve the ability to retain and recall information, more time should be spent studying.

1. Introduction

1.1 Research Problem

As current undergraduate students, these are the following reasons why each contributor to this paper sought insight into how to improve our ability to retain information. One area of interest was how the amount of sleep you get might affect memory retention. It is common among full-time students to sacrifice sleep to study, and finding out whether this type of schedule helps or hinders memory would be useful for students. Another area of interest was how anxiety-depression affects our memory retention during times of heightened internal stress. When increased stress occurs, we looked at whether cognitive processes are inhibited and the recall of information or memories becomes more challenging to recall. Other components of this research were investigating the impact of physical activity and the duration, frequency, and spacing of studying upon memory retention. Finding any variable that could improve the ability to retain information from lectures and apply that knowledge can greatly benefit students. In summary, we are looking to evaluate the factors that will affect or not affect the ability to retain and recall information.

1.2 Literature Review

One factor previously found to predict memory retention is the duration a person sleeps. For example, in an experimental study by Cousins et al. (2019), 29 adolescents from ages 15-18 were given 5 hours of sleep per night for 5 nights back-to-back along with a control group made up of 30 adolescents that were given 9 hours of sleep opportunity for the same period. After the 5-night sleep period, both groups were given detailed information about 6 ant and 6 crab species over 6 hours. Retention of the information was then tested 30 minutes and 3 days after learning by testing them on factual knowledge that was learned during the 6 hours. There was also a surprise test 42 days after learning in which 14 adolescents of the 5-hour group and 22 adolescents of the 9-hour group participated in a test of factual knowledge based on the initial 6-hour learning period. From all of the tests, the results showed that the group who was only given a 5-hour sleep opportunity per night experienced significant issues with retention. They showed a 26% increase in forgetting for the test that occurred 30 minutes after learning, a 34% increase in forgetting for the test that occurred 3 days after learning and a 65% increase in forgetting for the 42 days after the test. Based on these results, the researchers suggested that the less a person sleeps the less they will be able to retain information while learning. This also suggests that with more sleep and maintenance of good sleep habits, the better a person will be able to retain information and therefore improve their learning experiences.

A second factor previously found to predict memory retention is anxiety-depression. For example, in an experimental study by Darcet et al. (2014), researchers compared the memory performance of healthy control mice to an animal model of anxiety-depression created by giving a separate group of mice drops of corticosterone within the water for 28 days (about 4 weeks) before the testing and throughout the testing days. The mice were then given memory tasks to compare the natural (control) group to the depressed (experimental) group. The memory tasks were the Novel Object Recognition Test, Contextual Fear Conditioning, the Morris Water Maze, and the Barnes Maze, in order to measure episodic memory, associative memory, and visual-spatial memory. It was confirmed that the mice given corticosterone showed anxio-depressive-like behaviour, evaluated using the Open Field and the Splash tests. Furthermore, these mice displayed a decline of overall memory retention in the short- and long-term, less interest in the tasks of exploring, and lower discrimination, all characteristic of cognitive memory impairment. For example, depressed mice were observed to spend less time exploring a new object and be less motivated or able to locate the platform beneath the water that was explored in the days before. In contrast, the normal mice (control group) were observed to learn tasks and hold both short- and long-term memories to complete some of the same tasks on different days. Based on these results, the researchers suggested that the mice given corticosterone, and therefore feeling anxious-depressed, had more difficulty with all the memory tasks. This could help us understand why an anxious-depressed loved one may forget the butter when they shop at the store even though the grocery list is in their pocket.

A third factor previously found to predict memory retention is the level of physical activity. For example, in an experimental study by Van der Borght et al. (1997), researchers tested the effect of physical activity in mice on their capacity to form a new memory and how well they could retain it. In the experiment, 32 mice were held in two separate cages, 16 in each, one with a running wheel and one without. After 14 days, mice were given a day in a neutral cage to control for stimulation of the sympathetic nervous system before the tests. During the following 3 days, 8 mice from each cage were then set loose in a Y maze to form their memory of the maze. Over the next 4 days, half of the sedentary mice and half of the active mice were tested on their memory of the maze. The mice from the cage with the running wheel performed significantly better in navigating the pathway through the maze than the sedentary mice. Based on these results, the researchers suggested that exercise improved the learning curve of the Y maze by the rats leading to enhanced retention of how to navigate it.

A fourth factor previously found to predict memory retention is the spacing and duration of learning. For example, in an experimental study by Sisti et al. (2007), the researchers used two different experiments to study the effects of spacing out learning times on memory retention, and cell growth in the hippocampus and dentate gyrus. The experimental studies consisted of three groups using rats as subjects, one spaced learning group, one massed learning group, and a naive group which had no training. The rats were put through a Morris water maze where they had 90 seconds to find their way to the platform that was submerged slightly under the water at the end. The water maze consisted of a circular metal tank, barriers, and opaque white-colored water to create a challenge in finding the platform. After they had completed the maze, they were placed in a bucket for 60 seconds to avoid visual access to cues. In the first experiment, the spaced group was put through 4 learning trials per day for 4 days, and the massed group was put through 16 trials in one day. In the second experiment, the researchers assessed the rat's memory of the maze 2 days after the training had ended, and then again 2 weeks after the training had ended. The time between training was increased from 1 minute to 60 minutes and during this hour the rats were returned to their cages. In the first experiment, it was found that the animals in the spaced group outperformed navigating the maze than those in the massed group. In the second experiment, the first two trials showed similar results in both groups, and the trial after 2 weeks showed the spaced group significantly outperformed the massed group. Based on these results, the researchers suggested that spaced learning times are the most effective way to increase memory retention.

1.3 Hypotheses

Based on the above literature review, we predicted the following hypotheses:

- Hypothesis #1: If the amount of sleep increases then memory retention will increase.
- Hypothesis #2: If anxiety-depression increases then memory retention will decrease.
- Hypothesis #3: If physical exercise increases memory retention will increase.
- Hypothesis #4: If study time increases then memory retention will increase.

2. Methods

2.1 Participants

The 4 authors of this paper served as the participants in its studies. The participants ranged in age from 19-49 years old, with an average age of 29 years, and included 3 females and 1 male; all living in Victoria, BC, Canada. The participants were all undergraduate students at Camosun College who completed the current studies as an assignment for Psyc 110 "Experimental Psychology" and were grouped together due to their mutual interest in memory retention. Two participants had experienced anxious/depressive disorders, and one had experienced obsessive-compulsive disorder. Aside from those mental health difficulties, participants had regular eating, sleeping, studying and exercising habits. Three of the participants were returning to college after several years off and one was coming from secondary education with 1.5 years off between high school and college studies.

2.2 Correlational Study Methods

We first performed a correlational study to test concurrently all of our hypotheses by examining naturalistic daily changes in their variables longitudinally. Each participant recorded each of the following 5 variables: sleep, anxiety-depression, physical activity, study time, and memory retention.

2.2.1 Sleep

To measure sleep, each participant tracked when they went to sleep and when they woke up. We then calculated the total amount of sleep that each participant had per night in minutes.

2.2.2 Anxiety-Depression

To measure anxiety-depression we used 3 different methods. First, we measured heart rate by participants tracking their heart beats per minute using a timer and taking their pulse from the neck or wrist. Heart rate was recorded at three times per day: 8 am, 1 pm and 7:59 pm (one minute before the memory test). Second, participants recorded their total time of urination in seconds per 24 hours, tracking each day from 8 pm to 8 pm the following day. The time tracked per urination was counted in the head of the participant on some days, timed with a timer on some days, and estimated on some days. Third, a self-reported anxiety-depression measurement was taken on a subjective scale from 1-5, where 1 = none, 2 = mild, 3 = moderate, 4 = severe, and 5 = incapacitating. This report was taken directly before the word recall test and based on how we felt at that moment.

2.2.3 Physical Activity

To measure physical activity levels, a modified version of the Bouchard Physical Activity Log (see Appendix) was filled out daily by each of the participants. In this log, participants rated their level of physical activity on the following 1-9 scale: 1 = lying down, 2 = seated, 3 = standing, 4 = sedentary activity, 5 = light manual work, 6 = light sport or leisure activity, 7 = moderate manual work, 8 = moderate physical activity, and 9 =intense physical activity. The intensity and length of the physical activity was assessed at the moment to maintain the accuracy of the recording. The length of physical activity was measured in hours.

2.2.4 Study Time

To measure study time, the participants recorded 4 different variables. They measured the overall amount of time spent studying each day, the number of separate times the participant studied in the day, the average length of study sessions in the day, and the average spacing of time spent not studying in the day. We defined studying as participants sitting down to intentionally review words on the list that day using a variety of methods such as writing them down, mind mapping, reciting them verbally, or thinking about the words.

2.2.5 Memory Retention

To measure memory retention, each participant received a list of 20 randomized words at 8 am each day of the study. The list was generated using www.randomwordgenerator.com. The list was generated with no specific settings and the word type was set to all word types. Participants were then tested at 8 pm each day by being asked to recall as many words from the list of 20 words as possible. The score of the test was determined by the number of words that were remembered, out of a maximum possible score of 20. The set of words was different on each day of the study but were the same sets for each of the participants. Participants studied with no restrictions on study time or frequency.

2.3 Correlational Study Planned Analyses

To assess the strength and statistical significance of associations between variables predicted by our four hypotheses, we performed Pearson product-moment correlations of their predictor variables sleep, anxiety-depression, physical activity and study time with their outcome variable of memory retention. For testing Hypothesis #1, we correlated the hours of sleep and the number of words remembered. For testing Hypothesis #2, we examined correlations of heart rate, time spent urinating, and anxiety-depression subjective ratings with the number of words remembered. For testing Hypothesis #3, we correlated both the amount and intensity of physical activity with the number of words remembered. For testing Hypothesis #4, we correlated the overall amount of time spent studying, the number of times studying took place, how long each study session was, and how long the space was in between study sessions with the number of words remembered. We performed all of the above correlations separately for each participant as well as using data pooled across all of the participants. For the correlations using pooled data, in addition to using the raw data, we also performed correlations after we had first transformed the data from each participant into *z*-scores to standardize differences in averages and variability seen between the participants in their data and thus make them more comparable. A correlation coefficient was considered statistically significant if the probability of its random occurrence (p) was $< .05$ (i.e., less than 5% of the time expected by chance alone).

2.4 Experimental Study Methods

Based on the strength of the correlation between study time and memory retention we then chose to conduct an experimental study to test for a causal relationship between these two variables from Hypothesis #4.

We manipulated the independent variable, study duration, over eight days using an alternating (ABAB) design, with 4 experimental days and 4 control days per participant equally spaced over time to control for time effects. Control days were on days 1, 3, 5, and 7 and experimental days were on days 2, 4, 6, and 8 for Participants #2, 3, and 4. However, due to scheduling issues with Participant #1, their control days fell on days 1, 3, 5, and 6 and their experimental days fell on days 2, 4, 7, and 8. Each day participants were given a randomized set of 20 words at 8 am and tested for memory of these words at 8 pm. On experimental days participants studied for 5 minutes 3 times throughout the day (at approximately 9 am, 1 pm, 7 pm) equaling a total study time of 15 minutes. On control days participants studied for 5 minutes in 1 single study session, not later than 30 minutes before the random word test was given. The random lists of words were generated using the website https://randomwordgenerator.com. To avoid confounding variables, participants did not study 30 minutes before the test each day. It was not possible to control for placebo effects since participants could not be made unaware of whether they were receiving different amounts of study time. Although it was not entirely possible to eliminate the possibility of experimenter expectancy effects in our dependent variable (DV) measurements, this possibility was reduced by using an objective behavioural measurement of memory performance (number of words recalled), as compared to the use of subjective ratings. Since we had found in our correlational study that self-reported anxiety-depression was also highly correlated with memory, we measured our mood on a subjective scale (1=none, 2=mild, 3=moderate, 4=severe, 5=incapacitating) in the moments before taking the memory test in order to confirm that, on average, levels of this variable did not act as a confounding variable that systematically differed between the experimental and control days.

2.5 Experimental Study Planned Analyses

To assess the statistical significance of differences seen in memory retention 3-study session experimental days vs. 1-study session control days, Student's *t*-tests were performed. We performed *t*-tests separately for each participant as well as using data pooled across all of the participants. For the *t*-tests using pooled data, in addition to using the raw data, we also performed *t*-tests after we had first transformed the data from each participant into *z*-scores in order to standardize differences in averages and variability seen between the participants in their data and thus make them more comparable. An average difference between conditions was considered statistically significant if, using a one-tailed distribution (i.e., to determine if there is a difference between groups in a specific direction), the probability of its random occurrence (p) was

$< .05$ (i.e., less than 5% of the time expected by chance alone).

3. Results

3.1 Correlational Study Results

As shown in Table 1, we found that the characteristics of study time we examined (total study time, study session frequency, study session duration, and study session spacing) and ratings of anxiety-depression on a subjective scale were significantly correlated with memory retention. All other predictors showed no significant correlation with memory retention.

We found no support for the hypothesis that sleeping more would be associated with an increase in memory retention. Sleep amount was not significantly correlated with the number of words recalled for any single participant (all $r \leq 0.70$, all $p \geq .08$) nor when using either pooled raw data ($r = 0.22$, $p = 0.25$; see Figure 1) or pooled standardized data ($r = 0.24$, $p = 0.22$; see Figure 2).

We found mixed support for the hypothesis that increased anxiety-depression would be associated with a decrease in memory retention. Anxiety-depression measured indirectly by urination duration was significantly correlated with the number of words recalled in one participant ($r = -0.77$, $p = 0.04$; for all other participants absolute $r \leq 0.44$, $p \geq 0.34$) but was not significantly correlated when using either pooled raw data ($r = 0.04$, $p = 0.85$; see Figure 3) or pooled standardized data ($r = -0.17$, $p = 0.39$; see Figure 4). Anxiety-depression measured indirectly by heart rate was not significantly correlated with the number of words recalled for any single participant (all r ≤ 0.72, $p \geq 0.07$) nor when using either pooled raw data ($r = -0.15$, $p = 0.45$; see Figure 5) or pooled standardized data ($r = -0.21$, $p = 0.28$; see Figure 6). However, we did observe a significant correlation between anxiety-depression measured directly on a subjective scale and the number of words recalled in one participant ($r = -0.86$, $p = 0.009$; for all other participants $r \leq -.59$, $p \geq 0.06$) and when using either pooled raw data ($r = -0.64$, $p = .0001$; see Figure 7) or pooled standardized data ($r = -.72$, $p = .000005$; see Figure 8).

We found no support for the hypothesis that an increase in physical activity would be associated with an increase in memory retention. Time spent physically active was not significantly correlated with the number of words recalled for any single participant (all $r \leq 0.75$, all $p \geq 0.05$) nor when using either pooled raw data ($r = -0.01$, $p = 0.94$; see Figure 9) or pooled standardized data ($r = 0.14$, $p = 0.48$; see Figure 10). Similarly, the intensity of physical activity was not significantly correlated with the number of words recalled for any single participant (all $r \leq 0.74$, all $p \geq 0.06$) nor when using either pooled raw data ($r = -0.06$, $p = 0.75$; see Figure 11) or pooled standardized data (r = 0.24, $p = 0.22$; see Figure 12).

Support was found across the different characteristics of study time measured in this study for the hypothesis that an increase in study time would be associated with an increase in memory retention. The data for the overall study time had the strongest correlation with the number of words recalled, showing a significant correlation in one participant ($r = 0.84$, $p = 0.01$; for all other participants $r \leq 0.75$, $p \geq 0.05$), a trend towards significance when using pooled raw data ($r = 0.35$, $p = 0.07$; see Figure 13), and a highly significant correlation when using pooled standardized data ($r = 0.76$; $p = 0.0000007$; see Figure 14). Both the average duration and frequency of individual study sessions contributed to this association since they were each also significantly correlated with memory retention, albeit to lesser degree. The average duration of study sessions was not significantly correlated with the number of words recalled for any single participant (all $r \leq 0.72$, all $p \geq 0.07$) nor when using pooled raw data (r = 0.37, p = 0.05; see Figure 15), but was significant when using pooled standardized data (r = 0.38, p = 0.048; see Figure 16). The frequency of study sessions was significantly correlated with the number of words recalled for one participant (r = 0.85, p = 0.01), not significantly correlated when using pooled raw data (r = 0.25, p = 0.21; see Figure 17), and highly significantly correlated when using pooled standardized data (r = 0.65, p = 0.0001; see Figure 18). The spacing of studying was significantly correlated with the number of words recalled for one participant (r = 0.76, p = 0.04; for all other participants $r \leq 0.55$, $p \geq 0.22$), not significantly correlated when using pooled raw data (r = 0.27; p = 0.17; see Figure 19), and significantly correlated when using pooled standardized data (r = 0.42; p = 0.03; see Figure 20).

According to the pooled standardized data, the variable that demonstrated the strongest correlation with memory retention (r = 0.76) was the overall time spent studying.

3.2 Experimental Study Results

As shown in Table 2, a significant increase in memory retention was found with an increase in study time from 5 minutes on control days to 15 minutes on experimental days. Statistically significant differences between these conditions were seen using every single participant's data (all $p \leq 0.017$) and when using either pooled raw data (p = 0.000003; see Figure 21) or pooled standardized data (p = 0.00000004; see Figure 22).

To ensure this relationship between study time and memory recall was not artifact of anxiety-depression as a confounding variable, we also recorded self-reported anxiety-depression levels on control and experimental days. As shown in Table 3, no significant differences were found in the level of anxiety-depression between control and experimental days. Statistically significant differences were not found between these conditions seen using any single participant's data (all $p \leq 0.05$), pooled raw data (p = 0.50; see Figure 23), or pooled standardized data (p = 0.49; see Figure 24).

4. Discussion

4.1 Summary of Results

Based on previous research, we hypothesized that levels of memory retention could be predicted by four variables: sleep, anxiety-depression, physical activity, and study time. Data pooled and standardized across participants in our correlational study supported the predicted relationships of memory retention with anxiety-depression when measured on a subjective scale (Hypothesis #2) and with study time (Hypothesis #4) but not with sleep (Hypothesis #1) nor with physical activity (Hypothesis #3). The results of our experimental study established a causal role of study time upon memory retention.

4.2 Relation of Results to Past Research

For the hypothesis that as sleep increases so will memory retention, our results have shown that memory retention was not related to the amount of sleep someone had. This result is in contradiction to the study done by Cousins et al. (2019) since their findings suggested that with less sleep the less the student was able to retain when learning a new topic. Some possible reasons for this discrepancy in results could be the environment in which both studies took place. Our correlational study's sleep amount was tracked based on the amount of sleep each participant would get during a regular week in their life. This means the amount of sleep each participant got may be the amount they needed, or on days where it was not, the lack of sleep did not occur for the duration of the study. In the case of the study done by Cousins et al. (2019), the students were deprived of their regular sleep schedule for a week straight, creating an environment in which they were consistently exposed to sleep deprivation. This may have had a greater effect on memory retention than a day-to-day fluctuation of hours slept would have.

For the hypothesis that increased anxiety-depression would be associated with lower memory retention, we had mixed results based on the three types of anxiety-depression measurements we took in our correlational study. The correlation of subjective scale of felt anxiety-depression with memory retention supports previous research (Darcet et al., 2014) showing that an animal model of anxiety-depression, produced by giving mice heightened cortisol levels, had less memory retention. However, our data on heart rate and urine did not show a significant correlation with the retention of memory. This difference could be due to the fact that our subjective mood of anxiety-depression is a greater indicator of how much or little we will recall than our physical autonomic systems will display (our heart rate up to a certain point). The mice in the Darcet et al. (2014) study were given multiple cognitive and physical memory tasks to complete, in comparison to our research method of 20 words given in the morning and then recalled in the evening. Both studies show that when anxiety-depression is present, memory retention is hindered. Because of this correlational result we included the same measuring scale in the experimental phase of the research to determine if the effects of anxiety-depression would impact the results of our memory on control and experimental days as we altered our study duration between these days. The findings were that anxiety-depression was not able to account for the differences in memory retention we observed between experimental and control days. Because we did not experimentally manipulate anxiety-depression as an independent variable, we suggest further research be given to directly test memory under unaltered calm states of mind/body versus highly anxious mind/body states in order to examine whether a possible causal relationship exists between anxiety-depression and memory retention

For the hypothesis that a higher amount and intensity of physical activity performed would increase memory retention, the data negated the correlation. This result conflicts with the findings of Van der Borght et al. (1997) in which it is suggested that physical activity has a positive correlation with memory retention and recall. We can think of two possible rationales for these contradicting results. First, the Van der Borght et al. (1997) study was conducted using rats in a controlled environment in which all possible confounding variables were controlled for. This would lead the mice to only have the variable of physical activity to measure and might lead to a more accurate representation of the correlation between physical activity and memory retention. Second, the length of our correlational study was 7 days on 4 subjects, whereas the study by Van der Borght et al. (1997) spanned 3 weeks on 32 subjects. The limitation of time studied and the sample size may have hindered the ability to find a true correlation. The hypothesis was not supported in the end.

The hypothesis based on the Sisti, et al. (2007) study predicted that there would be an increase in memory retention associated with increases in study duration, frequency, and spacing. This was supported based on our correlational study results. Because our correlational research had examined four variables of study (overall time, session duration, session frequency and session spacing), we were able to distinguish overall study time as the study characteristics most strongly related to memory retention. We then focused our experimental study to determine whether increased time spent studying would increase recall. The results showed that with more time studied, more words were recalled. This confirms that increasing duration of time studied was in fact an indicator of better memory retention.

Unfortunately, we were not able to avoid placebo effects in our experimental study since there was no way participants could not know the amount of time they had spent studying. By including the subjective anxiety-depression mood scale we hoped to shed light on whether it had a confounding effect upon any differences between participants' memory outcomes other than study time. Taking into consideration the daily fluctuations of schedules, the participants stayed as close to the given timeframe for study times as possible, and the results of the experimental data showed significance for increased study periods to exhibit an increase in memory. In future studies of this hypothesis, the specified Time, Spacing and Duration could be followed more precisely, and each participant could have similar schedules during each day of research to lessen outside factors that may affect the results of the study.

4.3 Implications of Results

The practical implications of these results are relevant to students at any level of education and also to people looking to increase overall memory. Attending school means learning, processing and retaining the information given at lectures and within lessons, putting importance on the learner's study habits and lifestyle. Outside of the realm of education, these results could have meaning to anyone wants to improve memory of information in their day-to-day activities, in the workplace, or when remembering any new or relevant information. Being curious to understand what factors may increase or decrease the ability to retain information for exams, tests, papers, assignments, and overall knowledge of the subject being studied, we chose to observe a variety of factors that we predicted may have an effect. The data results showed very little correlation to any of the physiological measures (i.e., heart rate, urination, sleep, exercise). However, the data did show that study duration and perceived anxiety-depression levels were the primary predictors of better or worse retention of the 20 words we were given each day to recall. This study was originally conducted so that the four participants could find how to better retain and recall information to become better, more successful students. The research data collected found that the greatest factor was increasing the overall study time (study duration) to improve memory retention. Further experimental studies could be done manipulating levels of anxiety-depression to test its causal influence on memory retention. Our results are insightful for anyone looking to improve their memory skills, as we see that it takes time to encode new information and hold these ideas in memory to be used later. Our educational careers and our daily memory recall could be enriched by utilizing the data gained in this research by taking extra time to study, whether for a college course, the grocer list, or to remember a new person's name.

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Table 1
Correlation for study Variables

Variables	Participant #1		Participant #2		Participant #3		Participant #4		Pooled raw data		Pooled standardized data	
	r	*n*	*r*	*n*	*r*	*n*	*r*	*n*	*r*	*n*	*r*	*n*
Sleep amount & memory retention	-0.11	7	0.70	7	-0.28	7	0.65	7	0.22	28	0.24	28
Urination duration & memory retention	*0.19*	*7*	*0.35*	*7*	*-0.44*	*7*	*-0.77**	*7*	*0.04*	*28*	*-0.17*	*28*
Heart rate & memory retention	*-0.60*	*7*	*-0.43*	*7*	*-0.53*	*7*	*0.72*	*7*	*-0.15*	*28*	*-0.21*	*28*
Self-reported anxiety-depression & memory retention	*-0.59*	*7*	*-0.71*	*7*	*-0.86**	*7*	*-0.74*	*7*	*-0.64**	*28*	*-0.72**	*28*
Physical activity time & memory retention	*0.00*	*7*	*0.75*	*7*	*-0.60*	*7*	*0.43*	*7*	*-0.01*	*28*	*0.14*	*28*
Physical activity intensity & memory retention	*0.30*	*7*	*0.74*	*7*	*0.00*	*7*	*-0.08*	*7*	*-0.06*	*28*	*0.24*	*28*
Overall study time & memory retention	*0.84**	*7*	*0.75*	*7*	*0.71*	*7*	*0.73*	*7*	*0.35*	*28*	*0.76**	*28*
Study session duration & memory retention	*0.52*	*7*	*0.72*	*7*	*0.13*	*7*	*0.14*	*7*	*0.37*	*28*	*0.38**	*28*
Study session frequency & memory retention	*0.62*	*7*	*0.39*	*7*	*0.85**	*7*	*0.74*	*7*	*0.25*	*28*	*0.65**	*28*
Study spacing & memory retention	*0.55*	*7*	*0.41*	*7*	*-0.06*	*7*	*0.76**	*7*	*0.27*	*28*	*0.42**	*28*

* $p < .05$.

Table 2

Descriptive Statistics for Memory Retention Across Different Study Times

Condition	Statistic	Participant #1	Participant #2	Participant #3	Participant #4	Pooled raw data	Pooled standardized data
5 minutes of study time 3 times per day	*M*	13.00*	13.75*	12.25*	7.50*	11.63*	0.74*
	SD	*1.63*	*4.27*	*2.22*	2.65	*3.59*	*0.63*
	n	*16*	*16*	*16*	*16*	*16*	*16*
5 minutes of study time 1 time per day	*M*	4.25	5.75	7.25	3.50	5.19	-0.74
	SD	*4.19*	*3.40*	*2.06*	1.29	*3.04*	*0.56*
	n	*16*	*16*	*16*	*16*	*16*	*16*

Note. *M*, *SD*, and *n*, represent mean, standard deviation, and sample size, respectively. Number of words recalled out of 20 was used for the values shown above.

* $p < .05$ for comparison of 5 minutes of study time 3 times per day with its respective 5 minutes of study time 1 time per day.

Table 3

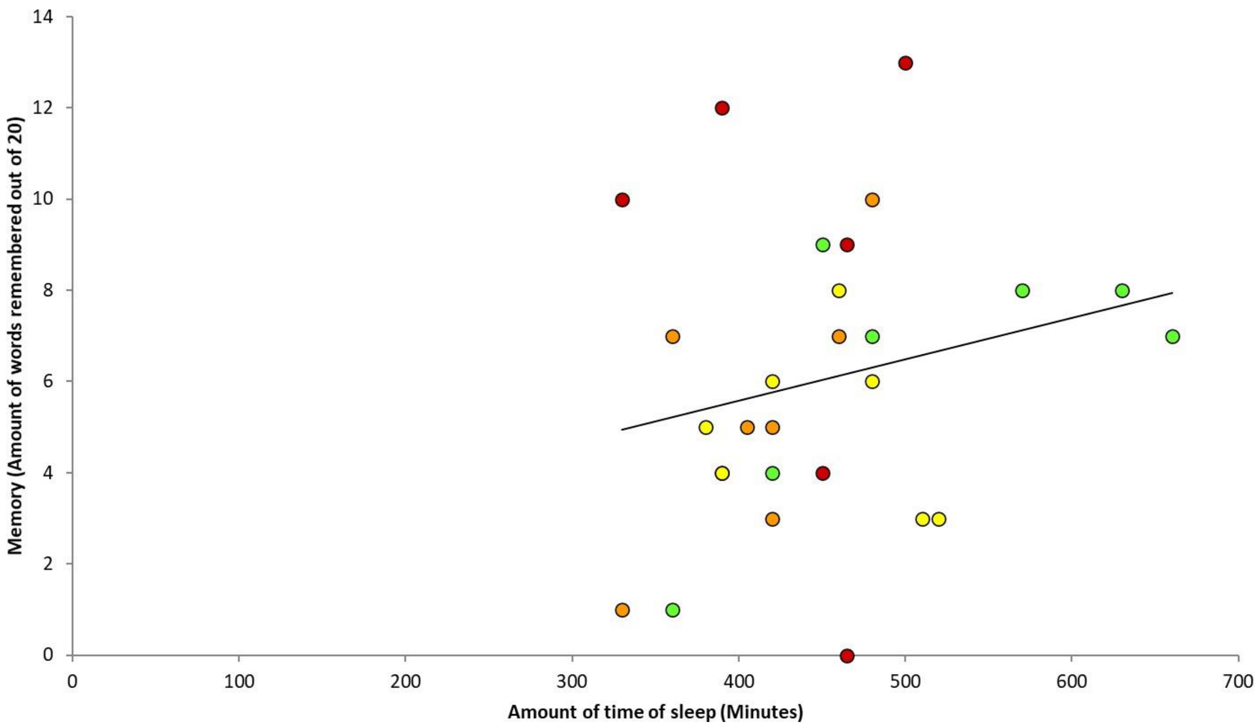
Descriptive Statistics for Anxiety-Depression Across Different Study Times

Condition	Statistic	Participant #1	Participant #2	Participant #3	Participant #4	Pooled raw data	Pooled standardized data
5 minutes of study time 3 times per day	*M*	4.00	2.13	2.00	3.75	2.97	-0.01
	SD	*0.82*	*0.63*	*1.41*	0.50	*1.24*	*0.98*
	n	*16*	*16*	*16*	*16*	*16*	*16*
5 minutes of study time 1 time per day	*M*	3.75	3.13	2.00	3.00	2.97	0.01
	SD	*0.5*	*0.85*	*0.82*	1.41	*1.07*	*0.96*
	n	*16*	*16*	*16*	*16*	*16*	*16*

Note. *M*, *SD*, and *n*, represent mean, standard deviation, and sample size, respectively. Level of anxiety-depression on a 1-5 subjective scale (where 1 = none and 5 = incapacitating) was used for the values shown above.

* $p < .05$ for comparison of 5 minutes of study time 3 times per day with its respective 5 minutes of study time 1 time per day.

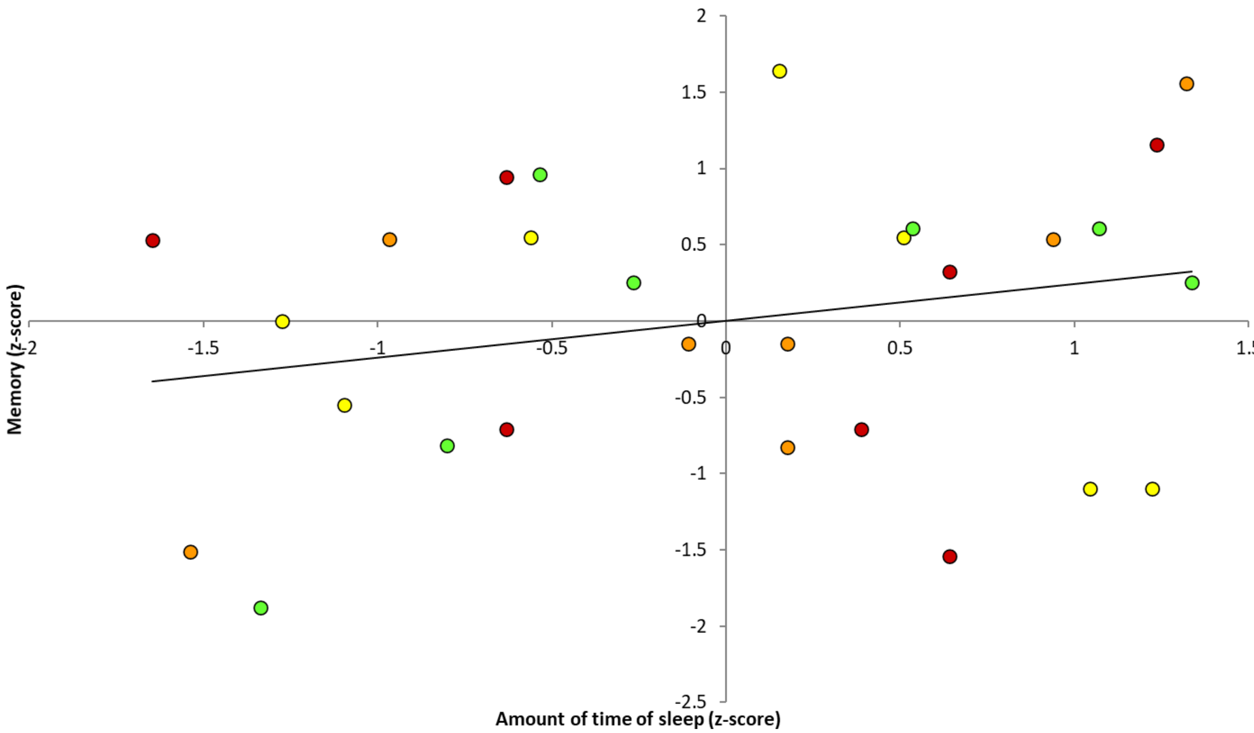
Figure 1
Association Between Sleep Amount and Memory Retention Using Pooled Raw Data



Notes. Marker colour differentiates participants: red = participant #1, orange = participant #2, yellow = participant #3, green = participant #4. Some data might not be visible in the figure due to overlapping markers.

Figure 2

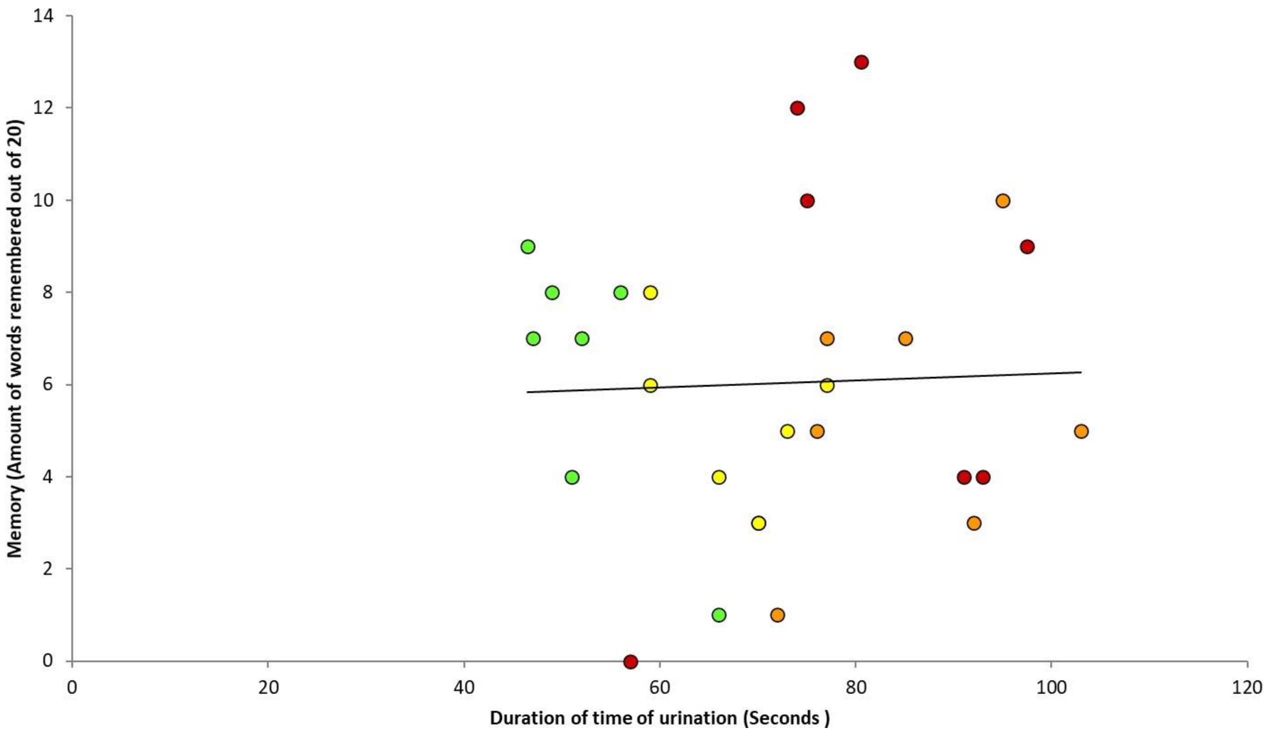
Association Between Sleep Amount and Memory Retention Using Pooled Standardized Data



Notes. Marker colour differentiates participants: red = participant #1, orange = participant #2, yellow = participant #3, green = participant #4. Some data might not be visible in the figure due to overlapping markers.

Figure 3

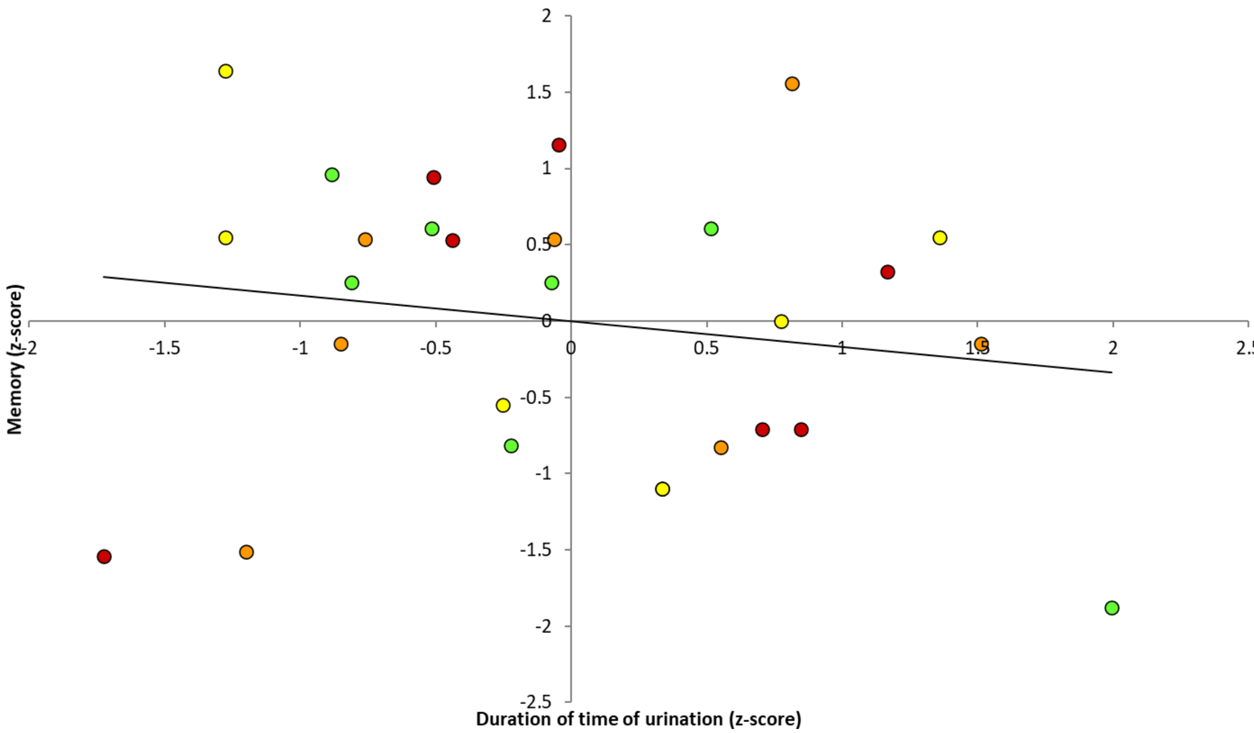
Association Between Urination Duration and Memory Retention Using Pooled Raw Data



Notes. Marker colour differentiates participants: red = participant #1, orange = participant #2, yellow = participant #3, green = participant #4. Some data might not be visible in the figure due to overlapping markers.

Figure 4

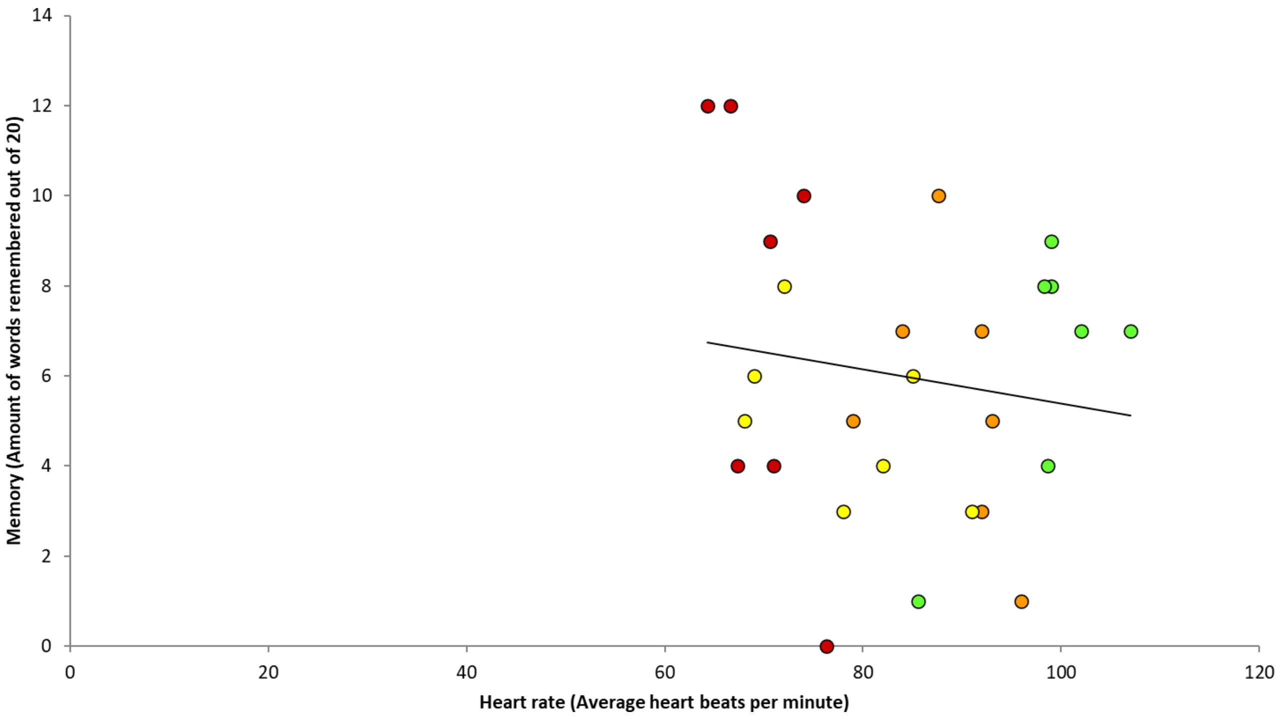
Association Duration of Urination and Memory Retention Using Pooled Standardized Data



Notes. Marker colour differentiates participants: red = participant #1, orange = participant #2, yellow = participant #3, green = participant #4. Some data might not be visible in the figure due to overlapping markers.

Figure 5

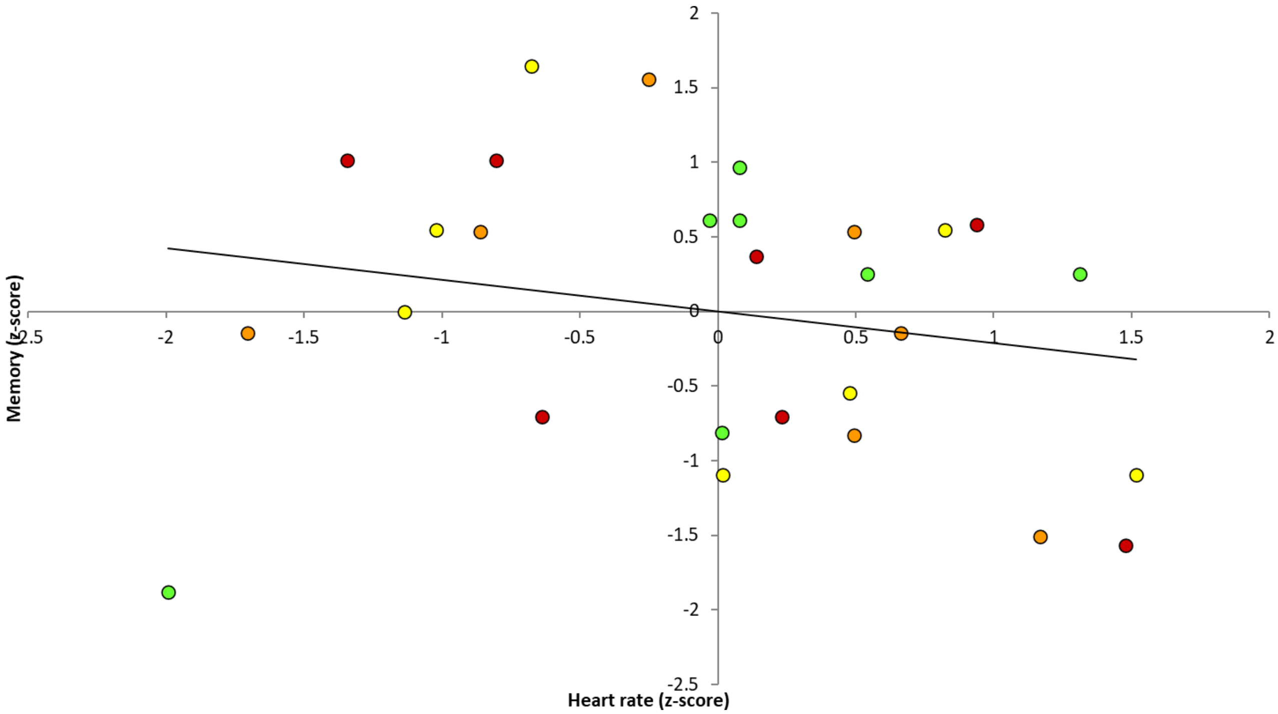
Association Between Heart Rate and Memory Retention Using Pooled Raw Data



Notes. Marker colour differentiates participants: red = participant #1, orange = participant #2, yellow = participant #3, green = participant #4. Some data might not be visible in the figure due to overlapping markers.

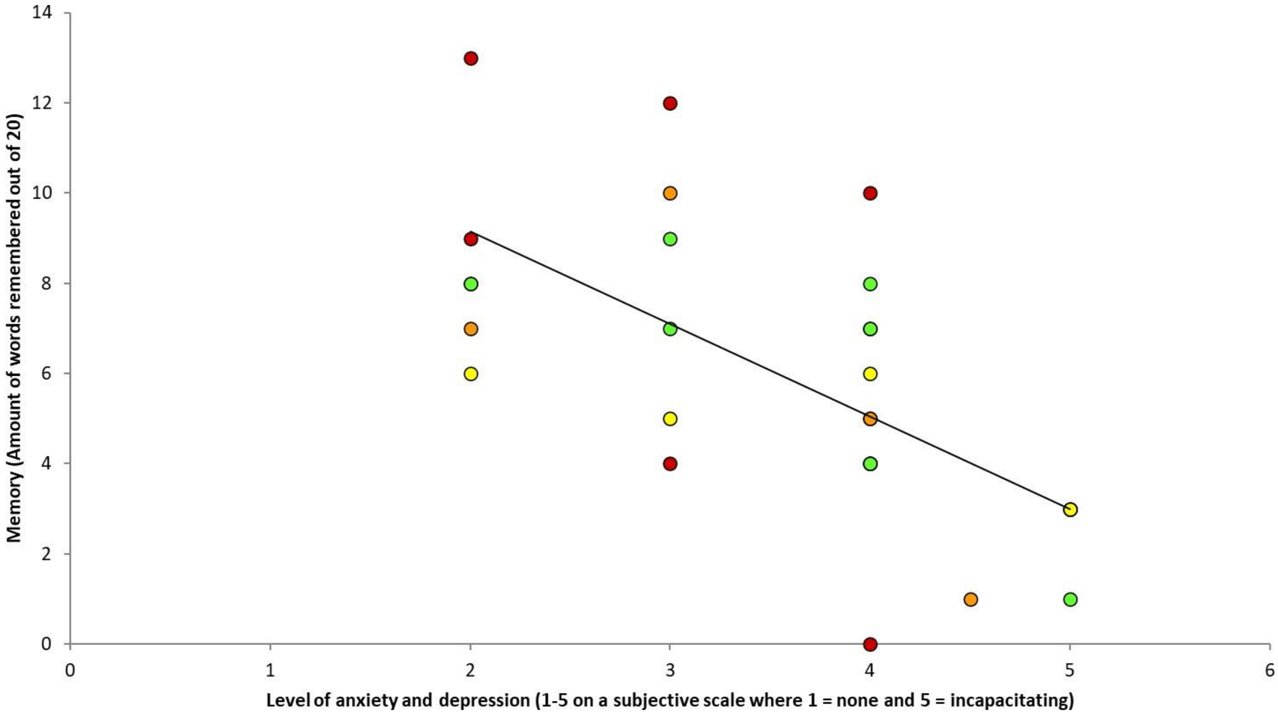
Figure 6

Association Between Heart Rate and Memory Retention Using Pooled Standardized Data



Notes. Marker colour differentiates participants: red = participant #1, orange = participant #2, yellow = participant #3, green = participant #4. Some data might not be visible in the figure due to overlapping markers.

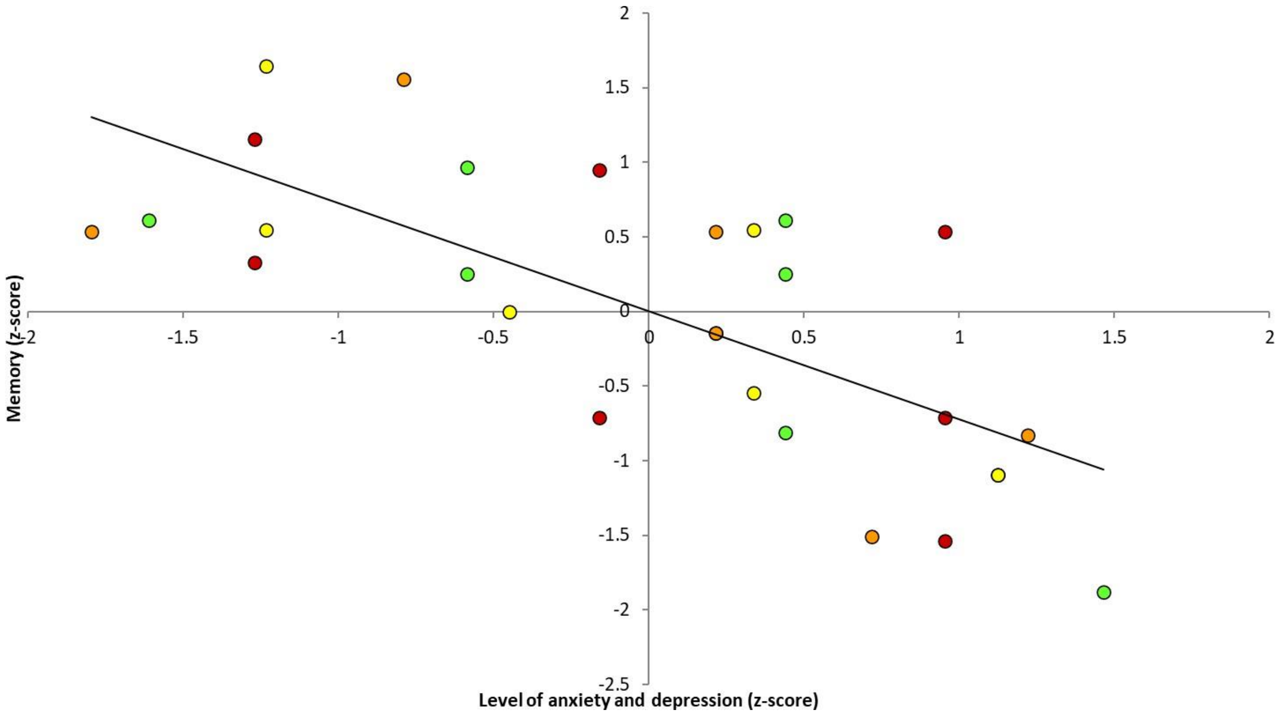
Figure 7
Association Between Self-Reported Anxiety Depression Scale and Memory Retention Using Pooled Raw Data



Notes. Marker colour differentiates participants: red = participant #1, orange = participant #2, yellow = participant #3, green = participant #4. Some data might not be visible in the figure due to overlapping markers.

Figure 8

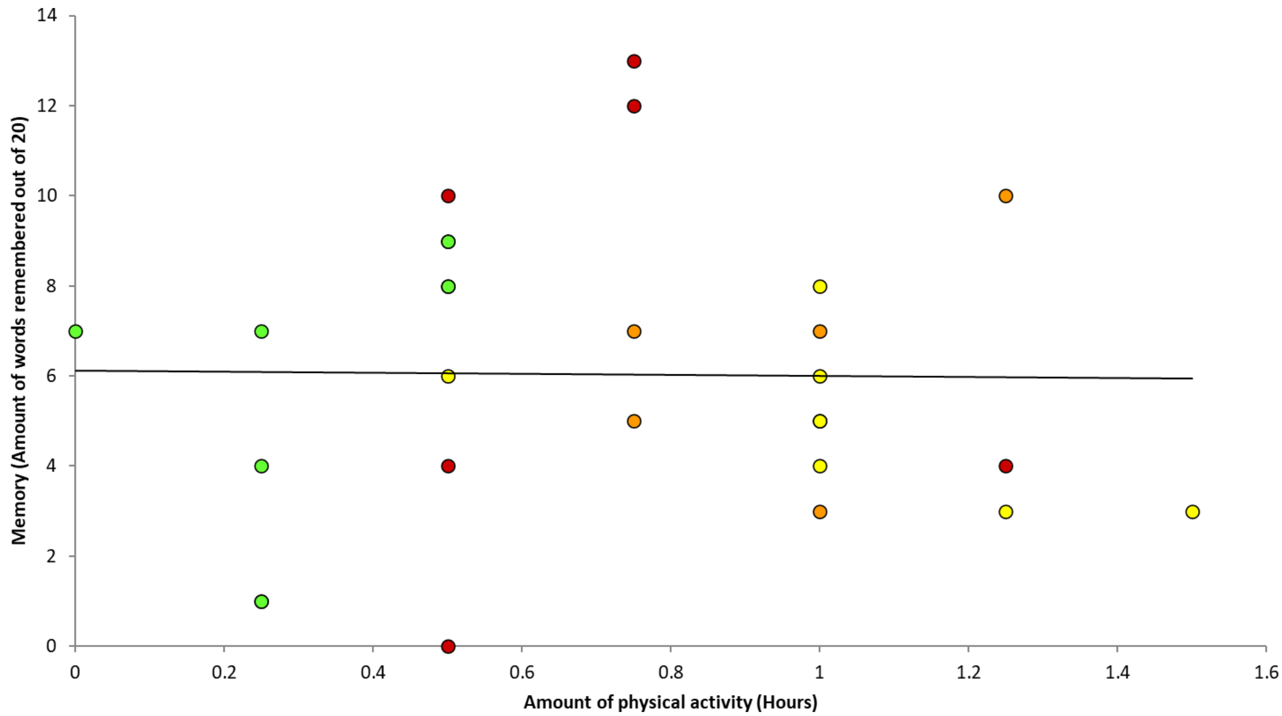
Association Between Self-Reported Anxiety Depression Scale and Memory Retention Using Pooled Standardized Data



Notes. Marker colour differentiates participants: red = participant #1, orange = participant #2, yellow = participant #3, green = participant #4. Some data might not be visible in the figure due to overlapping markers.

Figure 9

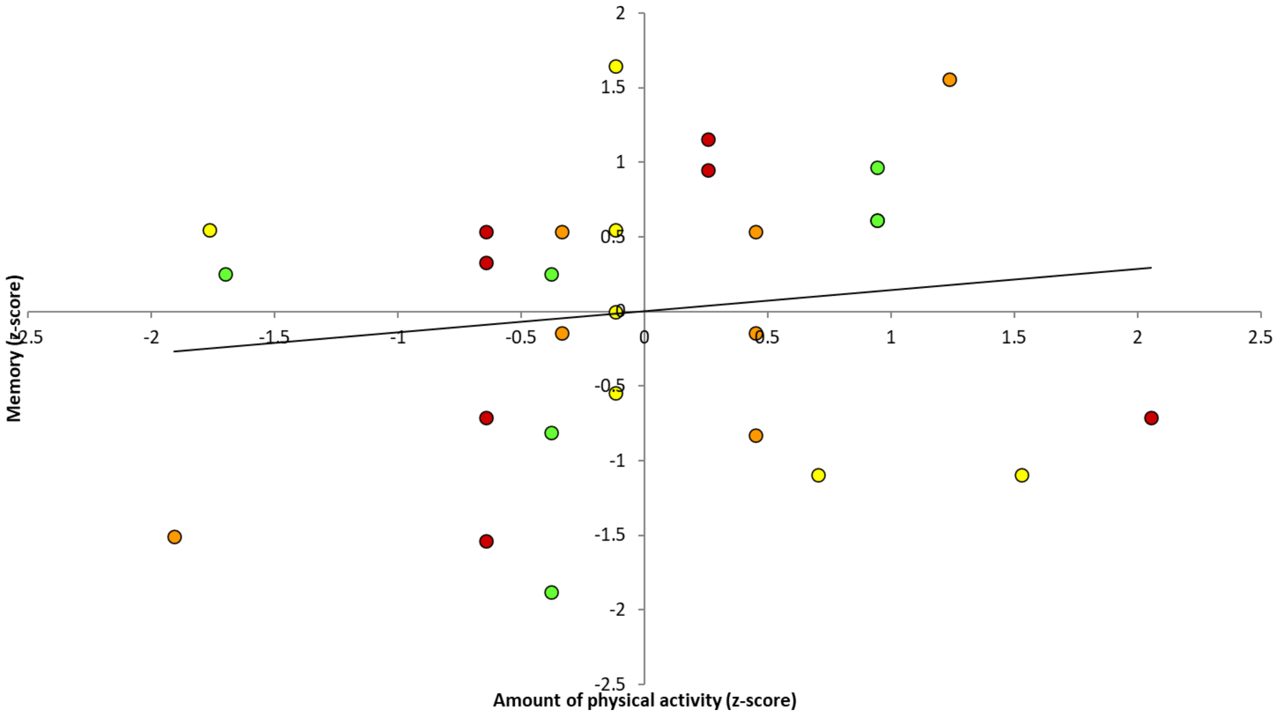
Association Between Hours of Physical Activity and Memory Retention Using Pooled Raw Data



Notes. Marker colour differentiates participants: red = participant #1, orange = participant #2, and yellow = participant #3 green = participant #4. Some data might not be visible in the figure due to overlapping markers.

Figure 10

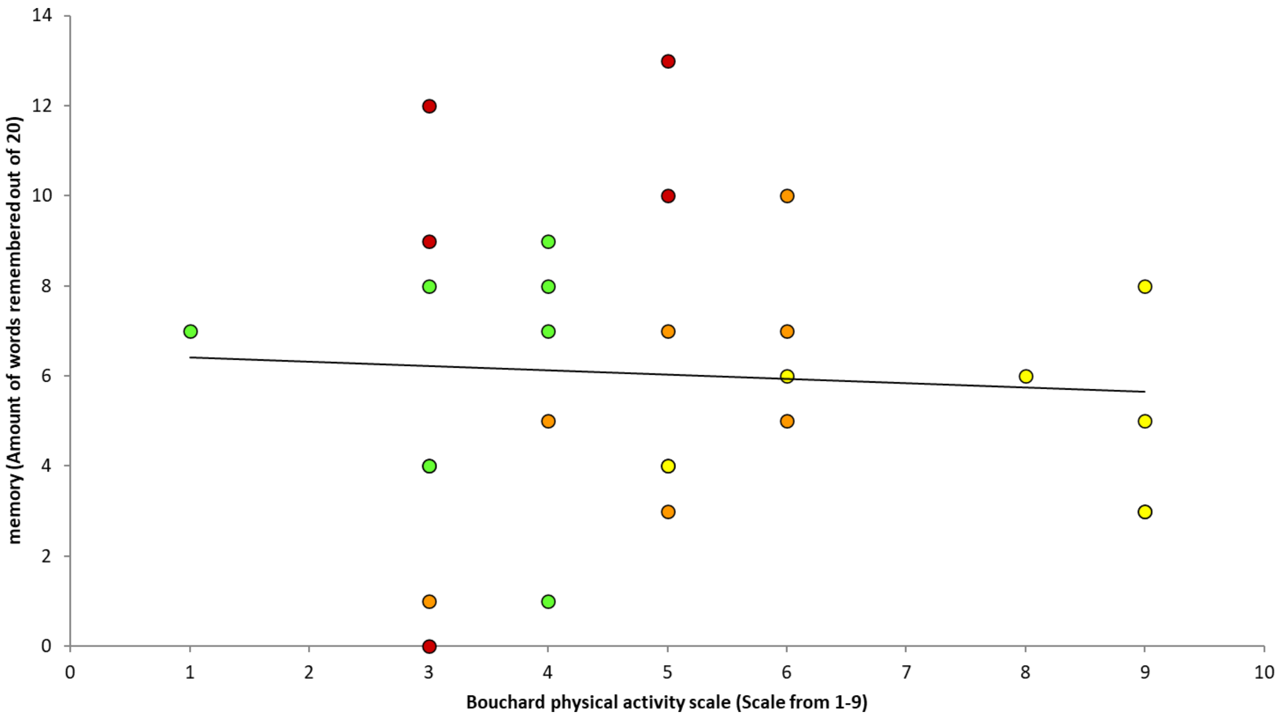
Association Between Hours of Physical Activity and Memory Retention Using Pooled Standardized Data



Notes. Marker colour differentiates participants: red = participant #1, orange = participant #2, and yellow = participant #3, green = participant #4. Some data might not be visible in the figure due to overlapping markers.

Figure 11

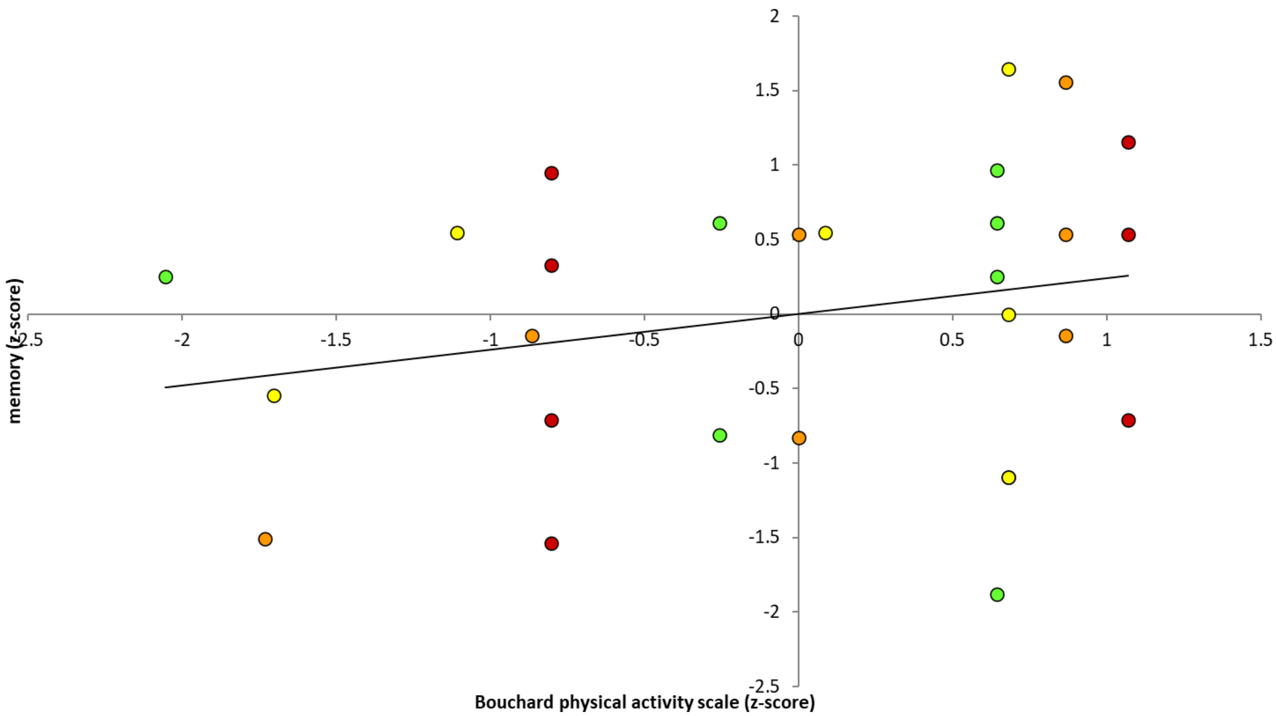
Association Between Intensity of Physical Activity and Memory Using Pooled Raw Data



Notes. Marker colour differentiates participants: red = participant #1, orange = participant #2, and yellow = participant #3, green = participant #4. Some data might not be visible in the figure due to overlapping markers.

Figure 12

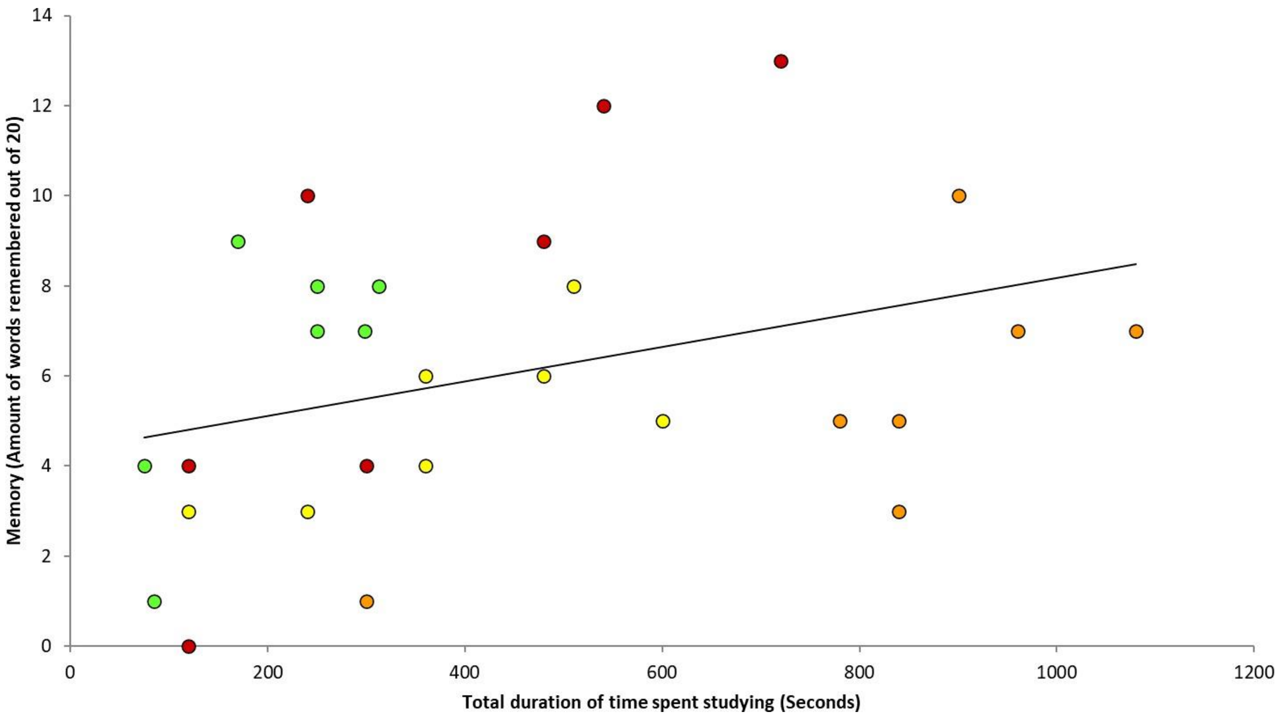
Association Between Intensity of Physical Activity and Memory Using Pooled Standardized Data



Notes. Marker colour differentiates participants: red = participant #1, orange = participant #2, and yellow = participant #3, green = participant #4. Some data might not be visible in the figure due to overlapping markers.

Figure 13

Association Between Overall Study Time and Memory Retention Using Pooled Raw Data



Notes. Marker colour differentiates participants: red = participant #1, orange = participant #2, yellow = participant #3, and green = participant #4. Some data might not be visible in the figure due to overlapping markers.

Figure 14

Association Between Overall Study Time and Memory Retention Using Pooled Standardized Data

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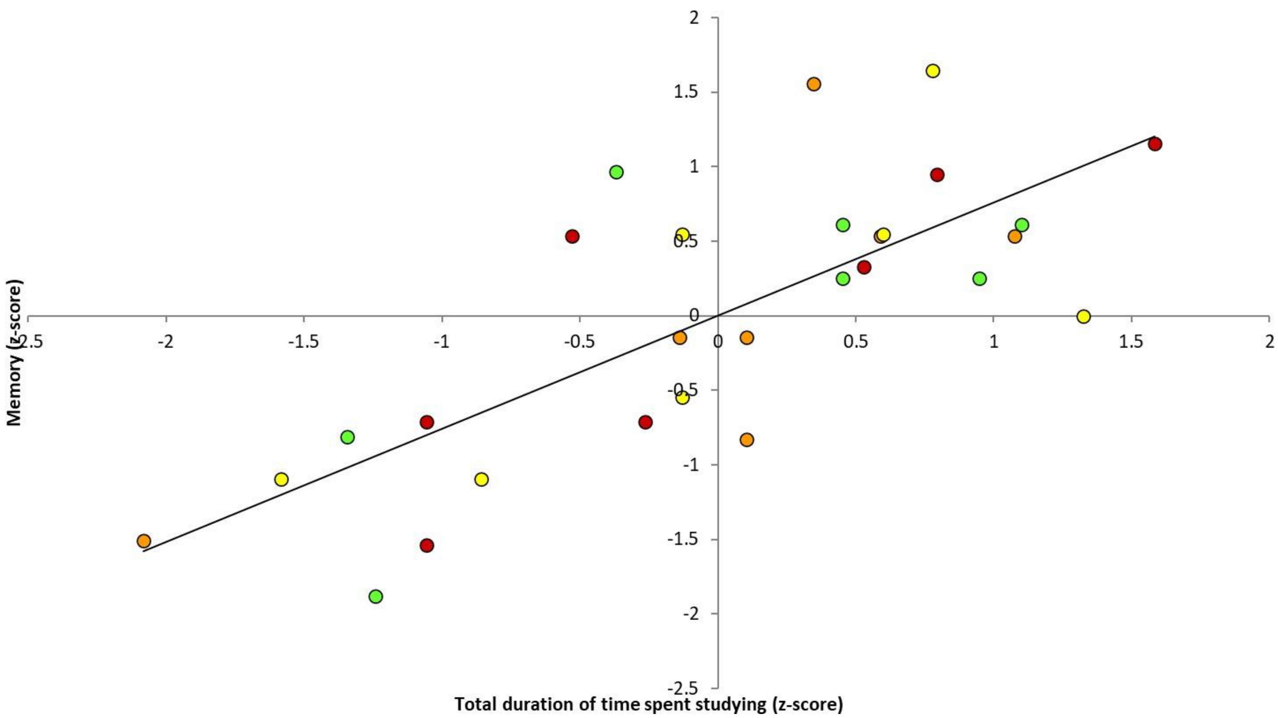
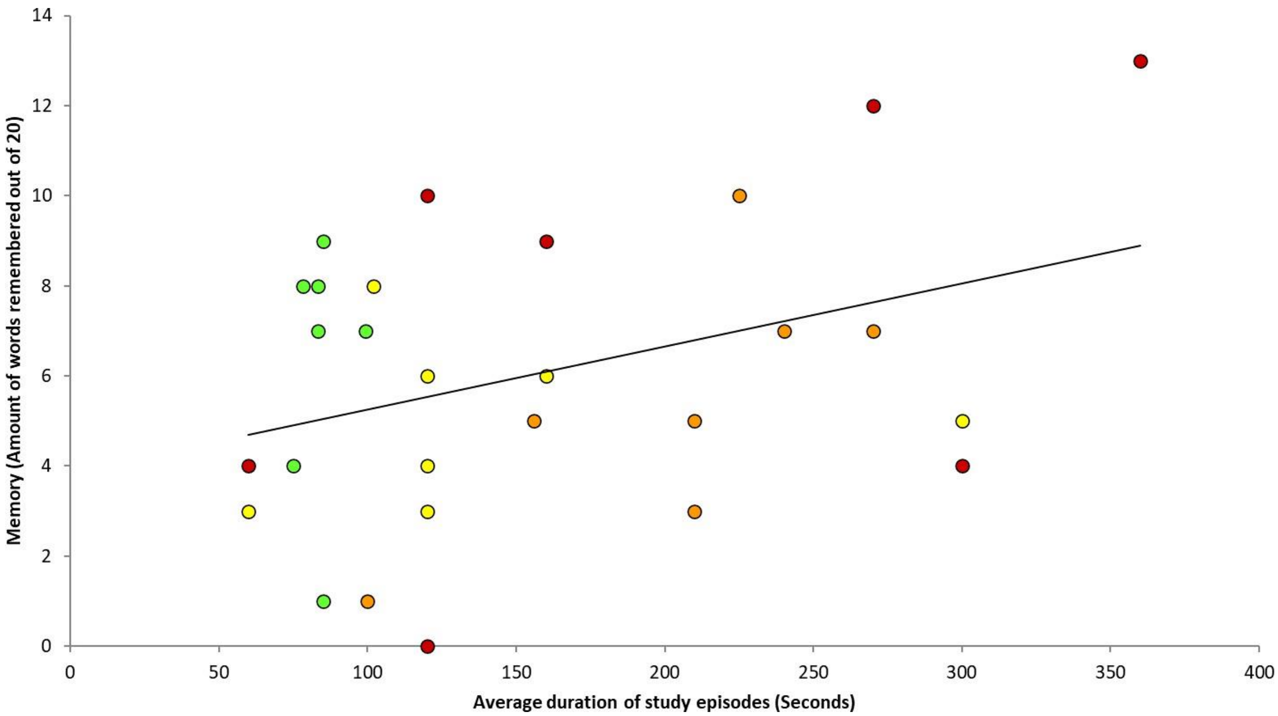


Notes. Marker colour differentiates participants: red = participant #1, orange = participant #2, yellow = participant #3, and green = participant #4. Some data might not be visible in the figure due to overlapping markers.

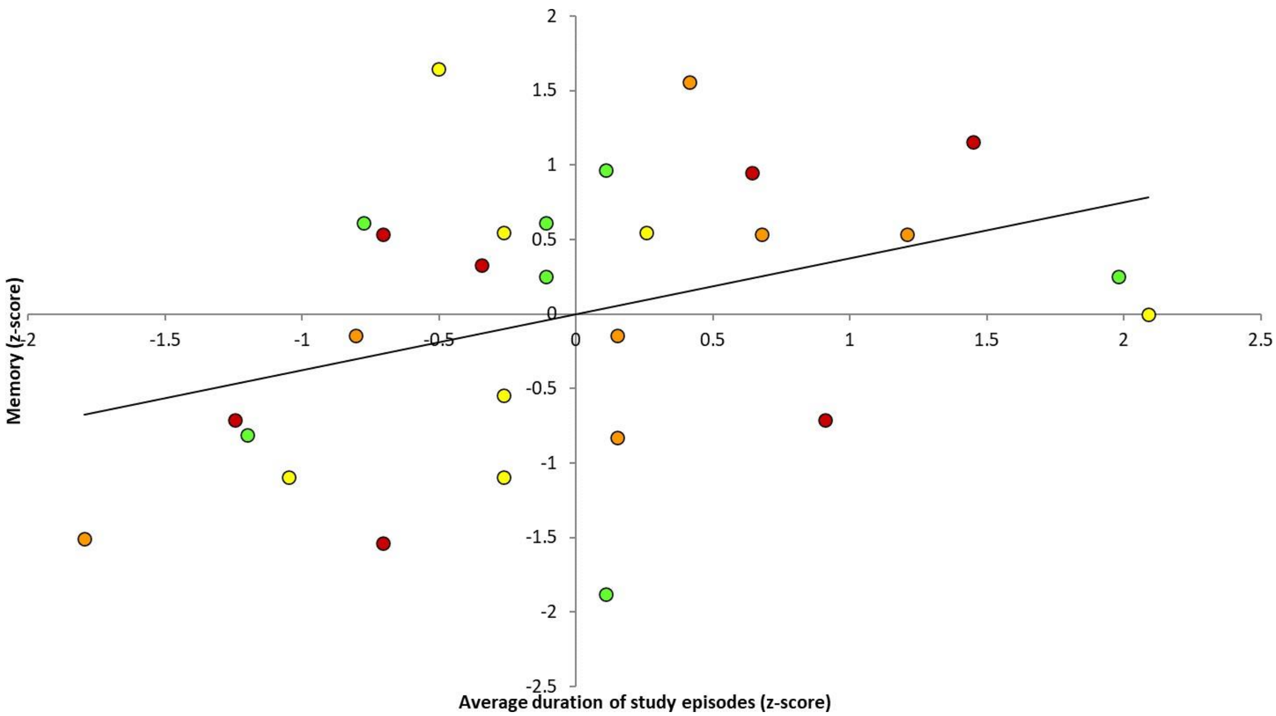
Figure 15

Association Between Study Session Duration and Memory Retention Using Pooled Raw Data



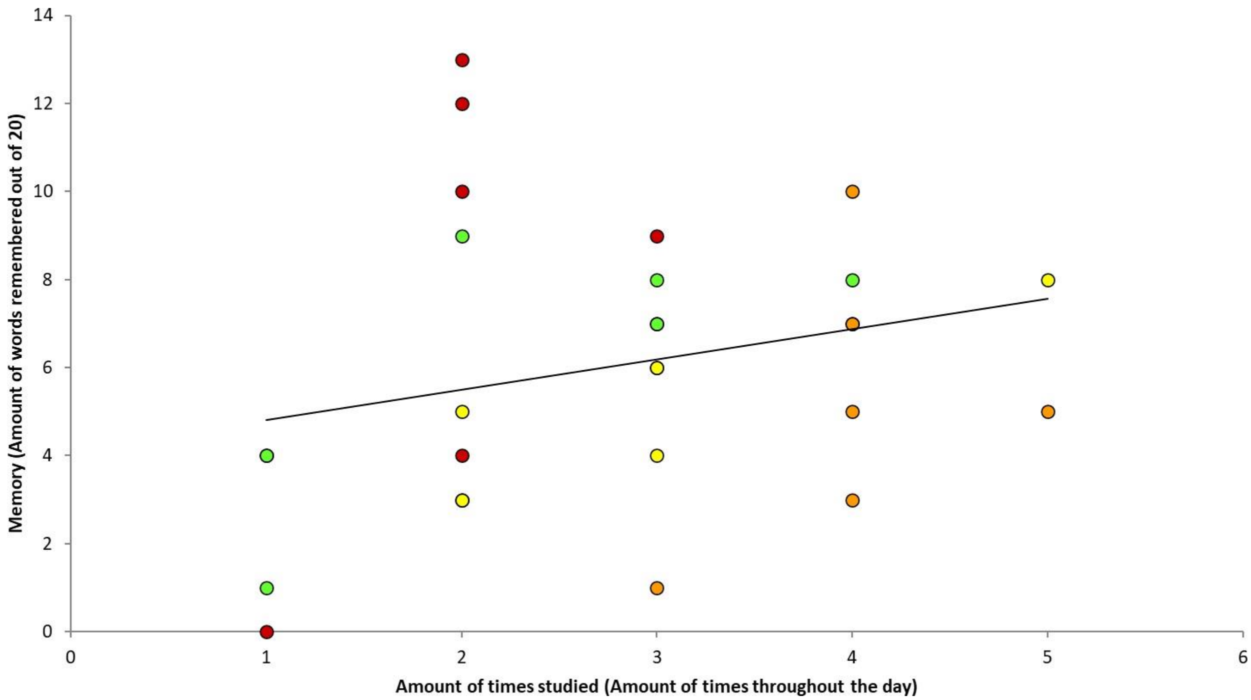
Notes. Marker colour differentiates participants: red = participant #1, orange = participant #2, and yellow = participant #3, green = participant #4. Some data might not be visible in the figure due to overlapping markers.

Figure 16
Association Between Study Session Duration and Memory Retention Using Pooled Standardized Data



Notes. Marker colour differentiates participants: red = participant #1, orange = participant #2, and yellow = participant #3, green = participant #4. Some data might not be visible in the figure due to overlapping markers.

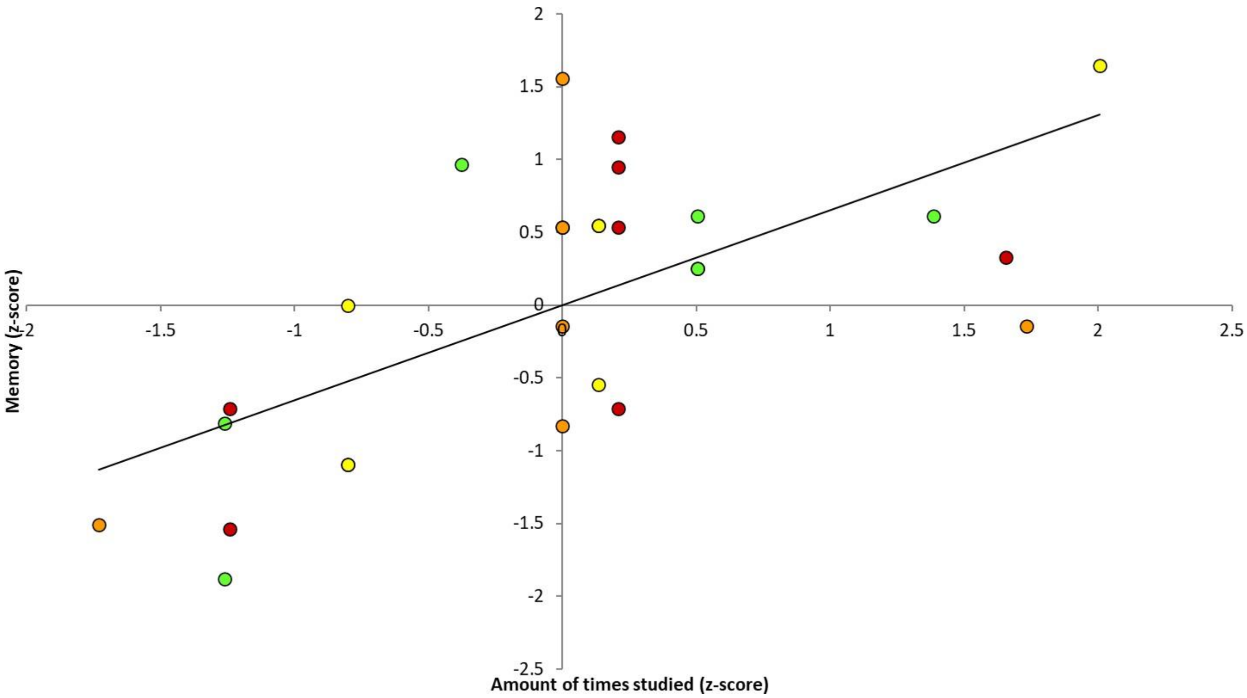
Figure 17
Association Between Study Session Frequency and Memory Retention Using Pooled Raw Data



Notes. Marker colour differentiates participants: red = participant #1, orange = participant #2, and yellow = participant #3, green = participant #4. Some data might not be visible in the figure due to overlapping markers.

Figure 18

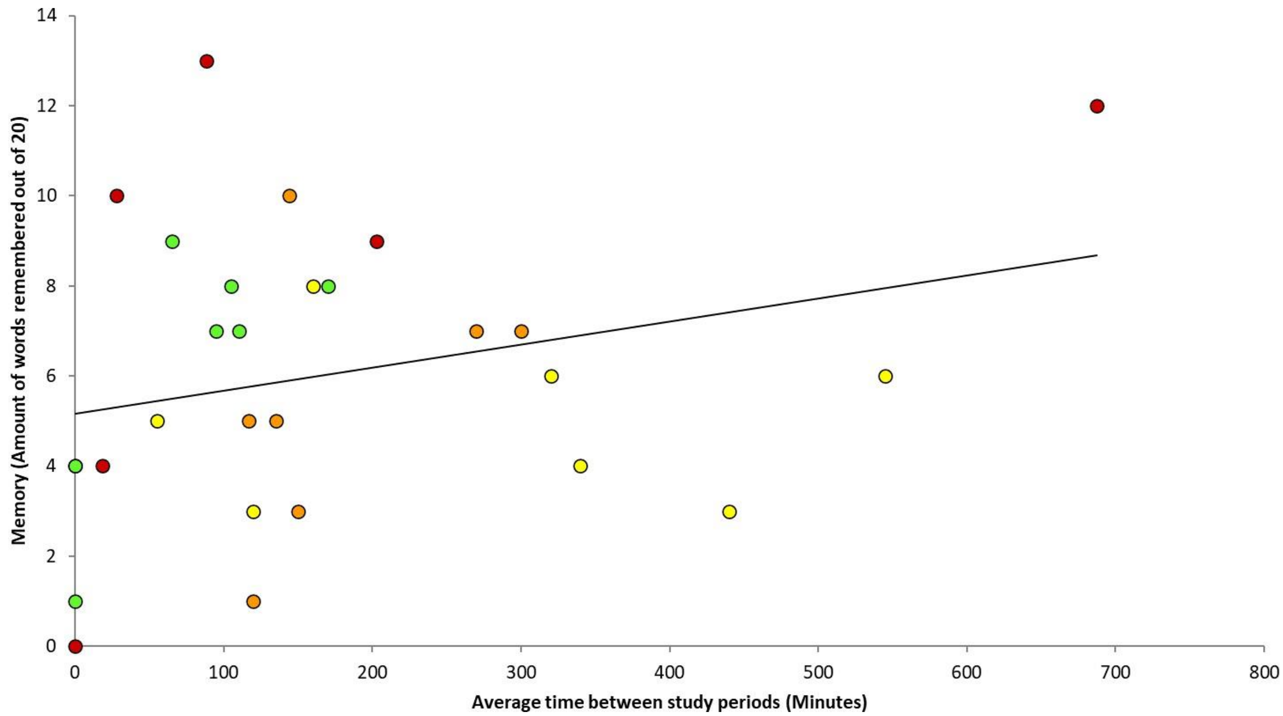
Association Between Study Session Frequency and Memory Retention Using Pooled Standardized Data



Notes. Marker colour differentiates participants: red = participant #1, orange = participant #2, and yellow = participant #3, green = participant #4. Some data might not be visible in the figure due to overlapping markers.

Figure 19

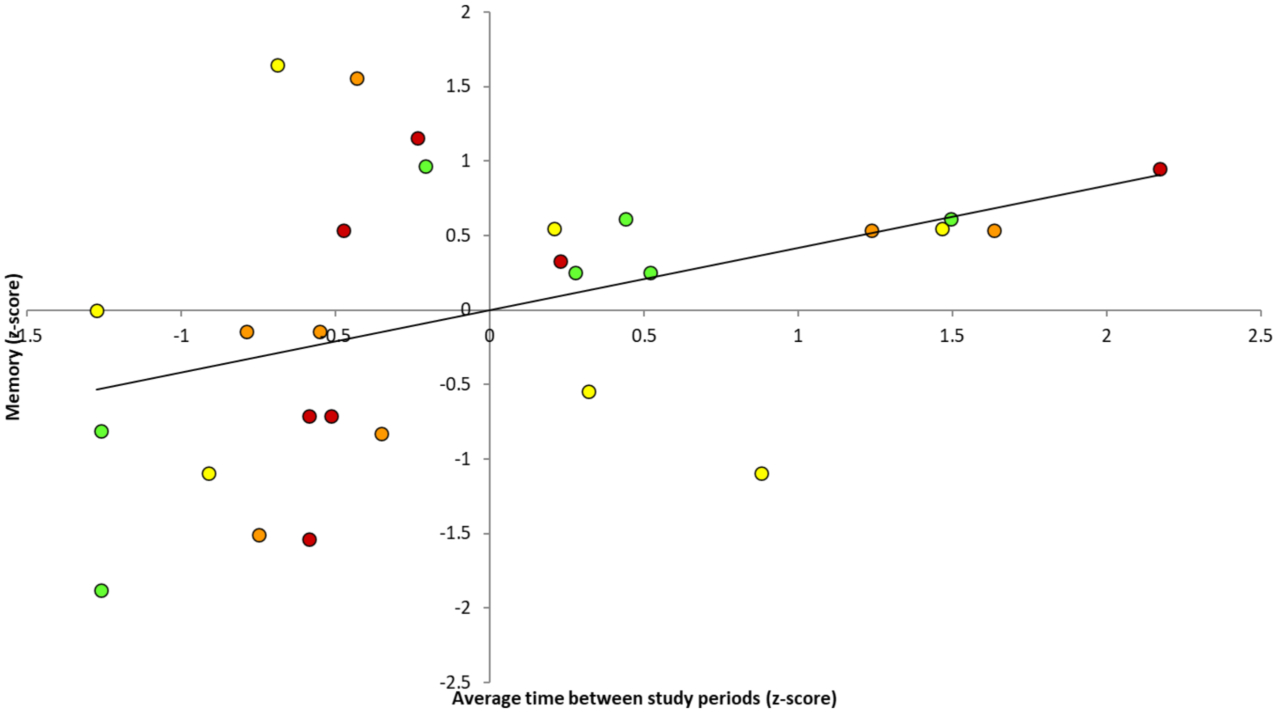
Association Between Study Spacing and Memory Retention Using Pooled Raw Data



Notes. Marker colour differentiates participants: red = participant #1, orange = participant #2, yellow = participant #3, and green = participant #4. Some data might not be visible in the figure due to overlapping markers.

Figure 20

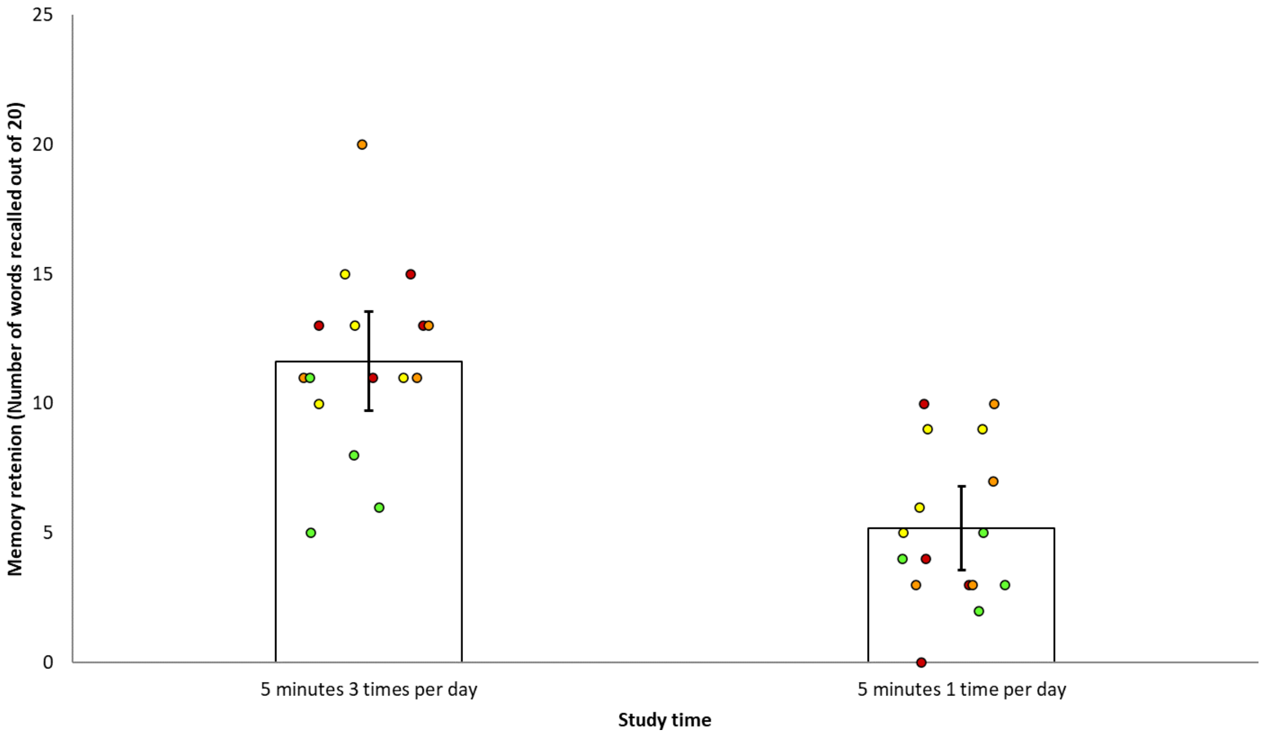
Association Between Study Spacing and Memory Retention Using Pooled Standardized Data



Notes. Marker colour differentiates participants: red = participant #1, orange = participant #2, yellow = participant #3, and green = participant #4. Some data might not be visible in the figure due to overlapping markers.

Figure 21

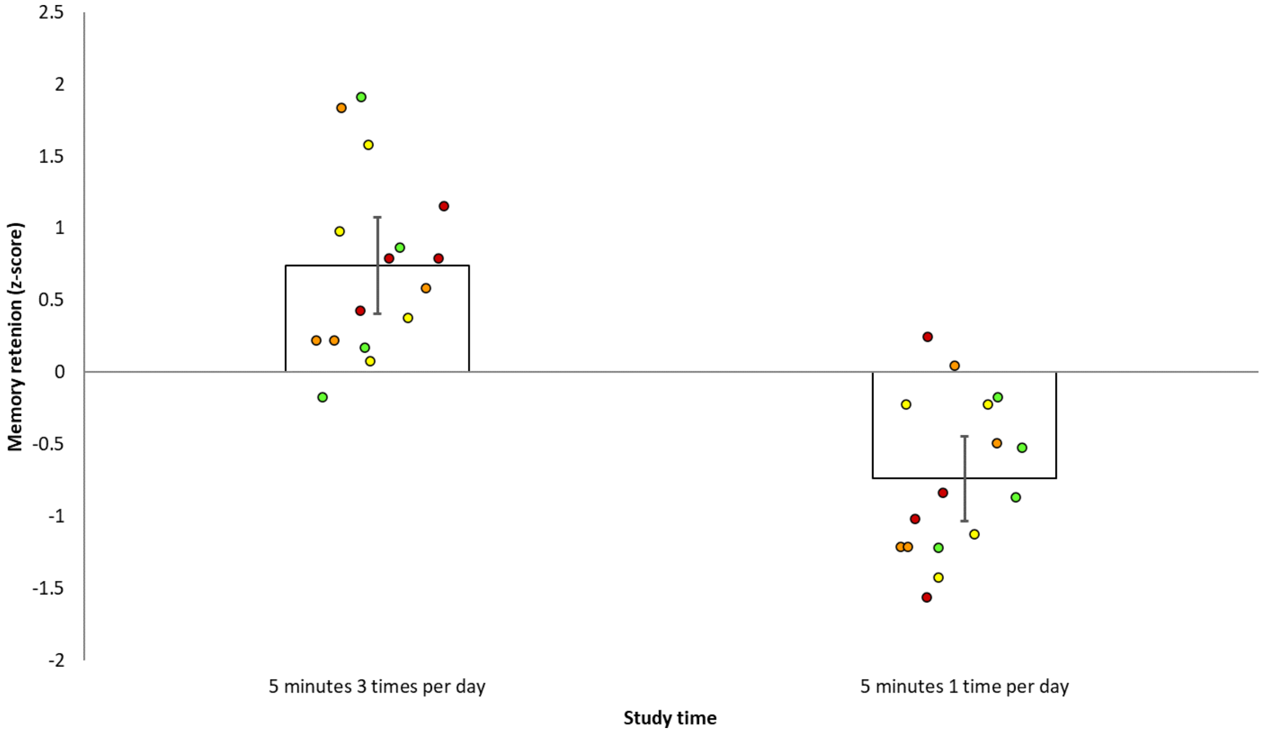
Average Memory Retention Across Different Study Time Conditions Using Pooled Raw Data



Notes. Memory retention scores are shown for the study period of 5 minutes 3 times per day and the study period of 5 minutes 1 time per day conditions using pooled raw data from all participants. Errors bars show ± 95% confidence levels. Overlapping scatterplot shows data from each participant. Marker colour differentiates participants: red = participant #1, orange = participant #2, yellow = participant #3, and green= participant 4.

Figure 22

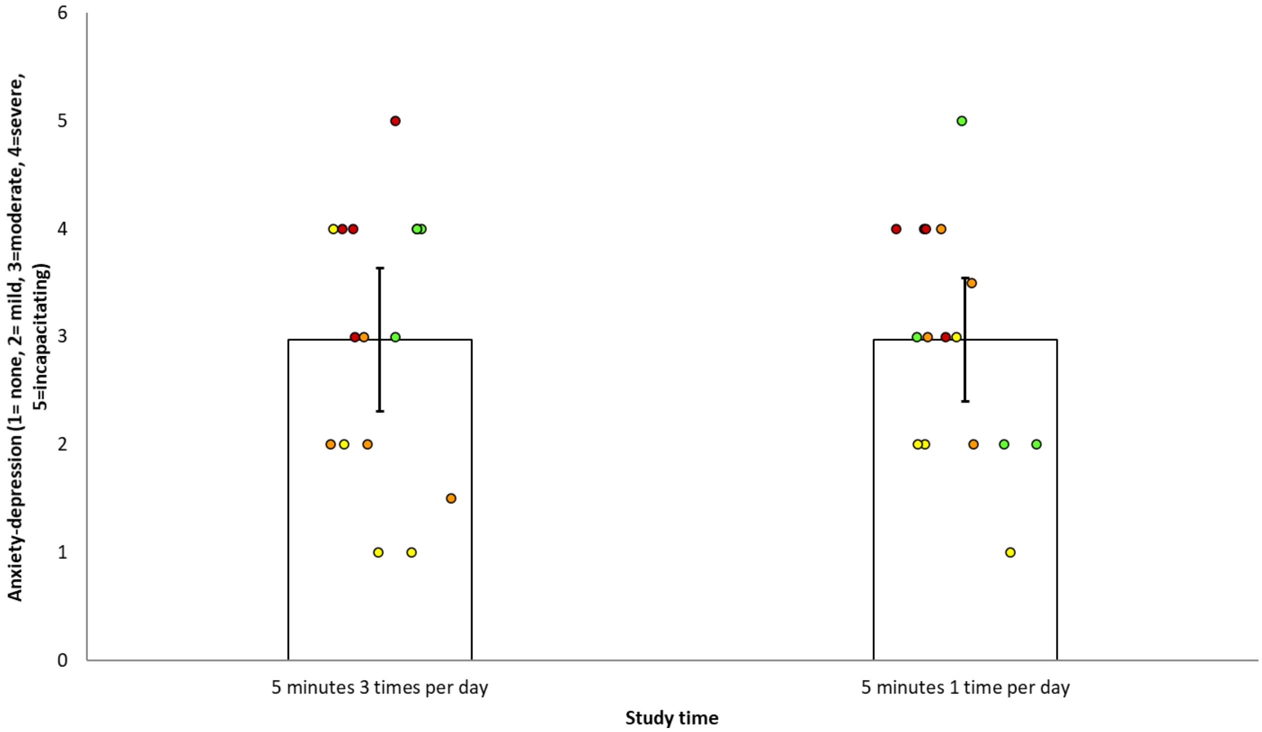
Average Memory Retention Across Different Study Time Conditions Using Pooled Standardized Data



Notes. Memory retention scores are shown for the study period of 5 minutes 3 times per day and the study period of 5 minutes 1 time per day conditions using pooled standardized data from all participants. Errors bars show ± 95% confidence levels. Overlapping scatterplot shows data from each participant. Marker colour differentiates participants: red = participant #1, orange = participant #2, and yellow = participant #3, and green= participant 4.

Figure 23

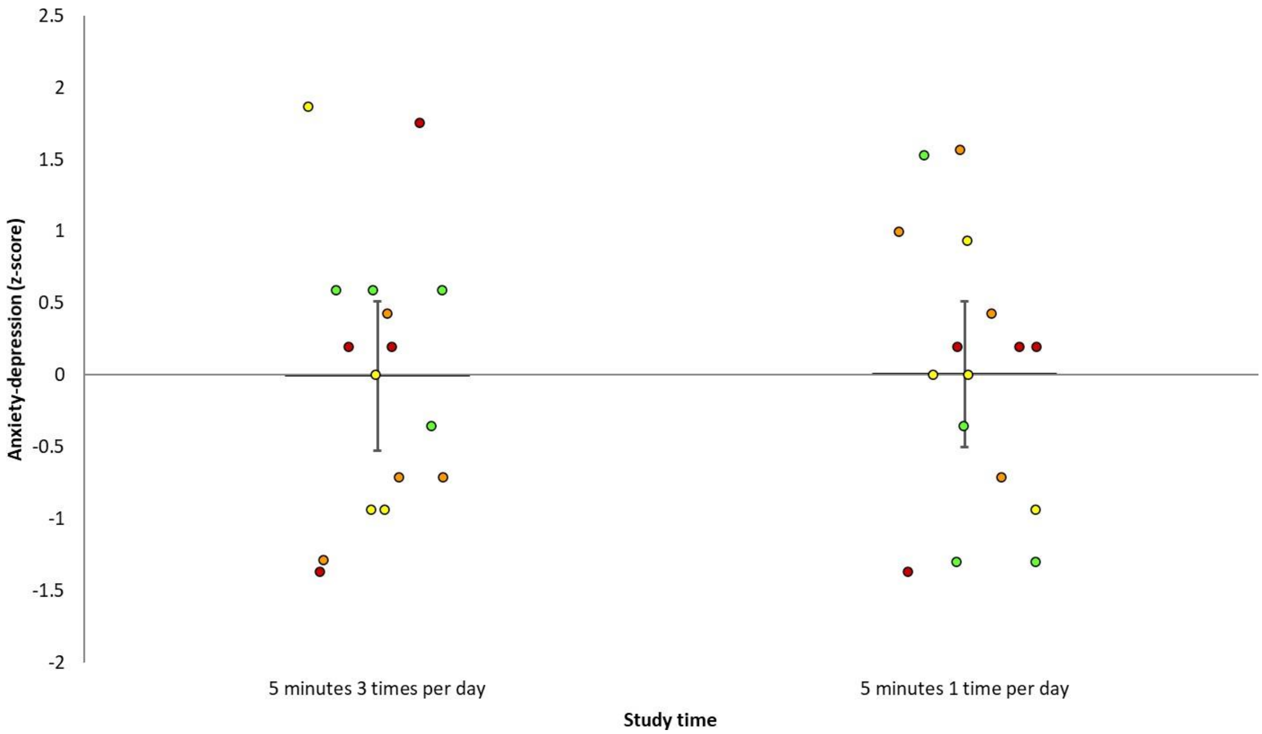
Average Anxiety-Depression Across Different Study Time Conditions Using Pooled Raw Data



Notes. Anxiety-depression scores are shown for the study period of 5 minutes 3 times per day and the study period of 5 minutes 1 time per day conditions using pooled raw data from all participants. Errors bars show ± 95% confidence levels. Overlapping scatterplot shows data from each participant. Marker colour differentiates participants: red = participant #1, orange = participant #2, and yellow = participant #3, and green= participant 4.

Figure 24

Average Anxiety-Depression Across Different Study Time Conditions Using Pooled Standardized Data



Notes. Anxiety-depression scores are shown for the study period of 5 minutes 3 times per day and the study period of 5 minutes 1 time per day conditions using pooled standardized data from all participants. Errors bars show ± 95% confidence levels. Overlapping scatter plot shows data from each participant. Marker colour differentiates participants: red = participant #1, orange = participant #2, and yellow = participant #3, and green= participant 4.

Appendix
Bouchard Physical Activity Record

Category of activity	Example of activity for each category
1	Lying down: - sleeping - resting in bed
2	Seated: - listening in class - eating - writing by hand or typing - reading - listening to the radio or T.V. - taking a bath
3	Standing; light activity: - washing oneself - shaving - combing hair - dusting - cooking
4	Getting dressed Taking a shower Driving a car Taking a walk (strolling)
5	Light manual work: - housework (washing windows, sweeping etc.) - tailor - baker - printer - brewer - cobbler - mechanic - electrician - painter - lab-work - carpentry - masonry - driving a farm tractor - cleaning trees - working in the chemical or electric industries - feeding animals on a farm - doing the bed Riding a moped Moderately quick walking (going to school, shopping)
6	Light sport or leisure activities: - light canoeing - volleyball - table tennis - baseball (except the pitcher) - golf - rowing - archery - ninepins - croquet - sailing - cycling (leisure)
7	Moderate manual work: - machine operating (building industry) - repairing a fence - loading bags or boxes - plantation work - forest work (machine sawing and log handling) - mine work - shoveling snow
8	Moderate sport or leisure activities: - baseball (pitcher) - badminton - canoeing - cycling (race bike) - dancing - tennis - jogging (slow running) - horseback riding - Alpine skiing - cross-country skiing (leisure) - swimming - gymnastics - brisk walking
9	Intense manual work: - felling a tree with an ax - sawing with a hand-saw - working with a pitchfork (on a farm) - cutting tree branches Intense sport or leisure activities: - running in a race - boxing - mountain-climbing - squash - cross-country skiing - ice hockey - basketball - football - racquetball