EFFECT OF COLD EXPOSURE ON MEMORY AND ATTENTION

by

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ABSTRACT

Research suggests a potential negative effect of cold exposure on cognitive abilities. The current study examined the impact of cold exposure due to environmental conditions (room temperature) on memory and attention. Using a within-subjects design, thirty participants were administered neuropsychological assessments, a state-anxiety measure, an objective body temperature measure, and two subjective perception ratings across two conditions: neutral and cold rooms. Results indicated significantly poorer performance in the colder condition on the memory recognition and commission errors on a test of sustained attention. This commission error score also was significantly correlated with the subjective measures of cold perception in the colder condition. Additional investigation is needed to further assess the potential relationship between cold temperatures and various types of memory and attention.

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CHAPTER I

LITERATURE REVIEW

Research relating to the psychological conditions experienced by polar explorers traces back to the late 19th century. The Belgica Expedition marks the first winter-over experience in Antarctica (Palinkas, 2003). Frederick A. Cook, one of the explorers, reported clear signs of depression and sadness among his fellow crew members. This depression may have been related to environmental factors (e.g., extreme physical environment) as well as to the limited social interaction (e.g., isolation or confinement). Over the years, the information once collected from the diaries of previous expeditioners now forms a subfield of psychology known as polar psychology.

There are currently 47 permanent research stations located throughout Antarctica under the control of 20 different nations (Palinkas & Suedfeld, 2008). The population of each station varies based on location and the time of year (Palinkas, 2003). Work and research personnel are psychologically and medically screened beforehand in order to minimize the risk of poor adaptation to the harsh conditions. Even with these screening procedures, however, approximately 5% of workers during the winter-over season experience symptoms that qualify for at least one psychiatric diagnosis based on the *Diagnostic and Statistical Manual of Mental Disorders* (DSM-IV) (Palinkas, Glogower, Dembert, Hansen, & Smullen, 2001). Although these rates may appear to be low, it is important to consider that these individuals undergo psychological screening procedures before the winter season. Expeditioners consistently report symptoms relating to their cognitive functioning, including impairment in tasks requiring memory, attention, and concentration (Palinkas & Suedfeld, 2008). However, the available research on this topic has suggested inconsistent findings on the relationship between the Antarctic conditions and cognitive performance.

In a related study of the relationship of cognitive performance to extended exposure working or living in a cold environment, Paul, Mandal, Ramachandran, and Panwar (2010) investigated the cognitive functioning of 24 (1 woman, 23 men) long-term residents stationed at Maitri, which is the Indian Research Base in Antarctica. Conditions for this study included exposure to 14 months of extreme cold temperatures, isolation, and confinement for the winter-over duty. Researchers utilized a within-subject design for their assessments that were performed at three different time points during the 14 months: the beginning phase (the second month), the middle phase (the seventh month), and the final phase (the twelfth month) (Paul et al., 2010). The middle phase was marked by extended darkness and limited confinement due to the winter season (i.e., average temperature of -24° C). Meanwhile, the beginning and final phases occurred during the summer season (i.e., average temperature of -5° C), which is characterized by extended light and less-restricted environments (e.g., access to outdoor activities). Assessments were administered in spaces at room temperature, which ranged from 18°C to 22°C.

Four different measures were administered: Task Acquisition to assess recognition memory, Delayed Recognition to detect deficits with retrieval, Attention and Concentration from the Post Graduate Institute (PGI) Memory Scale to measure short-term memory, and Digit Symbol Substitution of the WAIS-R to measure learning and memory (Paul et al., 2010). Results suggested that recognition memory, delayed recognition, and learning memory improved over time in a polar environment, whereas short-term memory was not affected throughout long-term residency. Researchers suggested that the improvements on three of the four measures may be due to gradual adaptation of the environment. In the beginning phase, participants were still adjusting to the new people and habitat, so these distractors may have influenced their initial performance.

This research suggests that exposure to cold temperatures may be associated with cognitive deficits, at least initially, particularly in measures of memory and attention (Paul et al., 2010). In a related body of research literature, studies in non-polar communities have been conducted to assess the impact of cold exposure manipulations on various memory and attention tasks. The following literature review will describe the findings from two types of empirical studies assessing cognitive functioning and cold exposure: studies examining the relationship between cold exposure using a cold pressor stress test and cognitive functioning and research focusing on cognitive functioning and exposure to setting/environmental temperature (e.g., room, water conditions). Finally, a study conducted to assess the impact of an environmental cold exposure on the memory and attention abilities of the participants is described.

Cold Pressor Stress and Neuropsychological Functioning

Experimentally manipulating one's exposure to cold and assessing cognitive functioning is a method used to evaluate the impact of temperature exposure in nonclinical samples. Several researchers have used a cold pressor task to experimentally manipulate cold exposure. Patil, Apfelbaum, and Zacny (1995) assessed the cognitive functioning of 14 volunteers (4 women, 10 men; mean age: 27 yrs) exposed to a cold pressor task. Individuals with any psychiatric or physical health concerns were excluded from the experiment. There were a total of 12 trials for this design which included six measures and two temperature conditions.

For each temperature condition, participants immersed their non-dominant forearms for three minutes into either the cold water (2-3°C) or warm water (37°C) (Patil et al., 1995). Individual assessments were performed during each three-minute immersion followed by a twenty-minute interval in which the participants removed their arms from the water to dry off before the next immersion. This process was repeated for each of the six measures across the two experimental sessions in which the temperature condition alternated (warm-cold-warm-cold-warm-cold and cold-warm-cold-warm-cold-warm). The researchers assessed memory functioning, specifically evaluating short-term memory. Participants were presented with a list of 20 words on a computer screen for a duration of 45 seconds. They then were given 90 seconds to write down as many of the words as they could remember. Results from this study found impaired performance for short-term memory during the cold water condition compared to the warm water exposure. When interpreting these findings, however, it is important to note the small sample size and that the measure used for assessing memory performance was not standardized. The authors also did not investigate gender differences for short-term memory, which may be due to the disproportionate number of men and women in the sample.

In more recent years, the cold pressor stress test has been implemented in various studies. Ishizuka, Hillier, and Beversdorf (2007) examined the impact the cold pressor test had on different types of memory. There were 16 (8 women, 8 men) college student participants for this study with a mean age of 23.8 years old. Those participants who reported a history of cold intolerance, irregular heartbeat, or a learning disability were excluded.

There were two test conditions designed for this study. Half of the participants were assessed with the cold pressor test on the first day, while the remaining half did not participate in the cold pressor test during the first session (Ishizuka et al., 2007). For the cold pressor condition, participants were instructed to immerse their hand for three minutes into the water (2-4°C). During each immersion, the cognitive tasks were performed. Researchers accommodated for the schedule of the cold pressor test; tasks that involved hand-written responses were performed during the non-dominant hand immersions, whereas the remaining tests were administered during the dominant hand submersions. After participants removed their hands from the cold water for 3 minutes, testing procedures were paused until they put their hand in the water again. The immersion procedures were continued until they finished all of the neuropsychological battery.

To assess verbal memory, researchers selected trials 1-5 of the California Verbal Learning Test, list A (CVLT). The Rey Complex Figure was used to examine spatial memory. The N-Back test was administered to assess working memory. The researchers reported a decrease in word recall on the CVLT for the cold pressor condition compared to the control condition. It took participants in the cold pressor condition a shorter time to recall the Rey Complex Figure when compared to the control condition; however, participants recalled fewer items for this measure during the cold water immersions. There were no significant findings for the remaining cognitive tasks the researchers examined, including working memory. These results suggest that cold temperature stress has a negative impact on verbal memory and spatial memory, but does not affect working memory. This study presents a strong methodological design and use of standardized measures for the assessments. Also, the researchers examined various aspects of memory, which include both verbal and visual domains. However, the study has a relatively small sample size, which may impact the utility of these findings.

Using a slightly larger sample, Duncko, Johnson, Merikangas, and Grillon (2009) assessed the cognitive functioning following a cold pressor task for 24 (12 women, 12 men) volunteers. The participants had an average age of 28.1 years. The DSM-IV as well as a physical examination and urine sample was used to determine the physical and mental health of each volunteer. Exclusions were made based on the presence of any current medical condition, drug usage, or a history of psychiatric illness. Random assignment was used to place the participants into either the stress group ($n = 11$) or the control group ($n = 13$). After physiological measures were administered, the participants began their assigned procedures. Individuals in the stress group were instructed to place their dominant hand initially into room temperature water (23°C) for a five-minute duration, then to submerge the same hand into ice water (0-2°C) for one minute. The volunteers within the control group placed their dominant hand into warm water (37°C) for five minutes.

Duncko et al. (2009) were primarily interested in assessing working memory performance, administering the Sternberg task to participants 20 minutes following the water immersions. Results from this study indicated shorter response times but more inaccuracy of responses for those in the stress condition compared to the control group. Although a methodologically sound study, one limitation could be the domains of memory that the researchers investigated. The authors examined visual recall and recognition feedback; however, they did not investigate the verbal memory counterpart.

Schoofs, Wolf, and Smeets (2009) also assessed working memory functioning when exposed to a stressful or non-stressful condition. The study included 71 male undergraduate students recruited from Maastricht University in Maastricht, Netherlands. Participants had a mean age of 20.18 years and did not report issues with past or current psychological or physical health. The experiment used a group comparison methodology and participants were placed in either the cold pressor test condition (n = 36) or the control condition (n = 35). Participants in the stress condition were asked to immerse their dominant arm in ice water (0-1°C) for as long as they could withstand with a maximum time limit of three minutes (Schoofs et al., 2009). The participants in the control group were instructed to place their dominant arm in warm water (37-40°C) until asked to discontinue. Immediately following the cold pressor task or the control treatment, participants were required to cover their arms with blankets and rest for three minutes. Assessments were performed after the resting period.

The researchers (2009) selected the Operation-Span task (O-Span task) and the Digit Span task to examine working memory performance. These measures were counterbalanced in the administration design. The O-Span task requires the participant to solve mathematical equations while also having to remember a list of unconnected words. Digit Span involves having the participant listen to a series of digits that increase in difficulty and then repeating the digits back to the examiner in either the same order or in reverse. Poorer performance in working memory was found in the stress condition for the O-Span task when compared to the control group. Impairment also was reported for Digit Span with the stress group; however, this finding was only evident for the backward subtest of this measure; there was no statistical significance between either of the groups for the forward subtest of Digit Span. One limitation with this research is that the sample consisted of only male students, so gender differences could not be examined for this study, even though research (McCullough & Yonelinas, 2013) has suggested that the stress from the cold pressor task may influence men and women differently when examining their memory performance. Another limitation may be the usage of the O-Span task. The authors stated that this measure is a working memory task; however, it also is a task that utilizes other executive functions. “Executive functions” is a generic term that encompasses a number of other cognitive processes. This needs to be taken into consideration when interpreting the findings because the O-Span task does not make it possible to make inferences as to which specific executive function was impaired by the cold pressor stress task.

Schwabe and Wolf (2010) examined the impact of cold stressor on memory performance during the learning process. Recruited from Ruhr-University Bochum in Bochum, Germany, there were 48 (32 women, 16 men) participants in this study. The volunteers had an average age of 23.6 years old. Random assignment was used to separate the participants into either the stress group or the control group. For the stress condition, participants placed their right hand into ice water (0-2°C) for three minutes (Schwabe & Wolf, 2010). Those volunteers in the control condition submerged their right hands into warm water (35-37°C). The materials for the assessment were presented to each condition during the water immersions. The participants listened to 32 different German words through a pair of headphones. The following day, participants went back to the laboratory to complete the free recall task. Once the free recall test was finished, the recognition test was administered to the participants. Results indicate that learning while under the stressful condition impaired performance for both free recall and recognition tasks compared to the control condition. No gender differences were reported. Two limitations of this project are the unequal number of gender participants and the lack of psychometric support for the assessment method utilized.

Finally, McCullough and Yonelinas (2013) recruited 40 (20 women, 20 men) undergraduate students from the University of California Davis to assess cold pressor effects on memory. Participants in the cold-pressor test group were asked to immerse their non-dominant arm in ice water (M = 0.6°C) for a maximum of three minutes or until they could not withstand the task (McCullough & Yonelinas, 2013). Meanwhile, those volunteers in the control condition followed similar procedures except they were asked to place their arm in warm water (*M* = 23.4°C). After a brief delay period, the recall and recognition tasks were administered. The stimuli consisted of 368 images that were presented to each participant in a randomized sequence. For the recall task, participants were given 10 minutes to recall as many of the pictures as they could by writing a brief description for each image. The recognition test included presenting the participants with 240 images—120 new images and 120 studied images. The testing process for the long-term assessment followed identical procedures. Three months after the initial procedures, 21 participants (11 women, 10 men) returned for the long-term memory portion of the research. Ten of these participants were originally assigned to the control group, while the remaining 11 participants had been assigned to the experimental group.

The results from this research suggest that cold exposure stress influenced males and females differently. It was reported that stress increased the recognition accuracy for males in comparison to the control group (McCullough & Yonelinas, 2013). For the females, results indicated a decrease in memory performance for participants in the stress condition. Stress also was shown to have different effects between genders for familiarity. For males, stress increased their familiarity for both the negative and neutral images. However, stress did not have a significant impact on familiarity for the females. There were no significant differences between the stress condition and the control condition for the recall task. For the long-term assessments, stress was shown to increase delayed recognition in males, but not the female participants. When interpreting this research, it is important to note that the materials used for assessing recall and recognition performance were not standardized procedures. Also, only approximately half (n = 21) of the original participants returned for the long-term memory assessments with the follow-up study.

Considering the literature on the impact of cold pressor tasks on memory performance, these studies have shown that auditory working memory seems to be impaired by the cold pressor task when compared to the control condition (e.g., Schoofs et al., 2009; Schwabe & Wolf, 2010). Poorer performances for spatial and verbal memory (Ishizuka et al., 2007) as well as short-term memory (Patil et al., 1995) also were reported in the cold pressor condition compared to control conditions. However, some of the findings presented in the literature suggested mixed results. For example, Duncko et al. (2009) found impairment in visual memory in the cold pressor condition, although Ishizuka et al. (2007) found no significant differences in visual working memory tasks when comparing the experimental condition and control condition. McCullough and Yonelinas (2013) examined differences in visual memory performance when accounting for gender influences. Along with gender differences for visual memory, these findings also suggested different results based on the task at hand such as recall, recognition, and delayed assessments.

Room Temperature and Neuropsychological Functioning

Assessing the relationship between room temperature exposure and cognitive performance also has been a focus of current research. Makinen et al. (2006) investigated cognitive performance in relation to controlled room conditions rather than the cold pressor stress task. This research involved 10 male volunteers with a mean age of 22.5 years old. A medical evaluation was performed in order to ensure the health of each potential participant. Participants were instructed to wear shorts, socks, and athletic footwear to the experiment. Participants initially were placed in the control condition room (25°C) for 90 minutes, and then the cognitive assessments were administered. Immediately after the control condition, the same participants were placed into a different room in order to examine cognitive performance in cold exposure (10°C). Participants were placed in this room for a two-hour duration. The remaining 20 minutes in each condition were set aside for the cognitive assessments. Volunteers participated in each procedure for 10 consecutive days.

The Automated Neuropsychological Assessment Metric for Isolated and Confined Environments (ANAM-ICE) was administered to assess domains of cognitive performance (Makinen et al., 2006). Certain measures on this assessment investigate memory, attention and concentration, and cognitive processing. Attention, concentration, and verbal learning were measured using the WAIS-R, Digit Symbol, and Symbol Digit Modalities Test, which were grouped as code substitution and code substitution delayed tasks. A continuous recall task was chosen to assess working memory performance. Another measure utilized in the methodology is a matching-to-sample task, which examines attention, spatial memory, short-term memory, and working memory. The Sternberg Memory Search assesses both visual memory and short-term memory.

Results indicate both impairment and improvement in cognitive performance depending on cognitive task (Makinen et al., 2006). There were no significant changes for the control condition across the 10-day period when examining the accuracy of the cognitive tasks; however, a significant increase in performance for accuracy in the cold condition over the duration of the study was observed for the code substitution, code substitution delayed, and Sternberg Memory tasks (Makinen et al., 2006). Collectively, these measures assess attention and concentration, visual memory, and short-term memory. Efficiency for the cognitive tasks showed improvement for the control condition for the following measures: code substitution and continuous performance. For the cold exposure, improvement in efficiency was reported for the code substitutions, matching-to-sample, and continuous performance tasks. These measures examine attention and concentration, spatial memory, short-term memory, and working memory. When evaluating the measures individually, poorer performance for accuracy was reported for the cold condition when compared to the control for both the Sternberg Memory Search and the continuous performance task. These results suggest that the influence cold exposure may have depends on the given cognitive function being assessed. One limitation to the design of this study is the small sample ($N = 10$) that consisted of only men. Another limitation may be the order of their procedures. For each of the 10 days, cognitive assessments were given in the control condition first, and then the cold condition immediately after. It would be interesting to see the results after counterbalancing the room conditions.

In a similarly designed study, Muller et al. (2012) recruited 10 male college students (mean age: 23 yrs) for their research assessing impact of room chambers to control for temperature exposure. The study took place across three consecutive days during which volunteers were exposed to the cold condition (10° C) for two hours and then a rewarming condition (25°C) for another two hours, with cognitive assessments being performed at four distinct periods throughout the procedure: baseline in the rewarming condition, 60 minutes into the cold exposure, 60 minutes after being removed from the cold exposure, and then 300 minutes after removal from the cold exposure (Muller et al., 2012). Researchers chose the Integneuro™ test battery to assess cognitive functioning. Specific content on this battery includes attention, working memory, and spatial memory. The Digit Span task was used to assess both working memory and attention. Another measure within this test battery is the Executive Maze Task, which assesses spatial memory performance.

Results from this research indicate that certain aspects of cognition are impaired when exposed to the cold condition. A decline in performance was reported for the Digit Span task during the cold exposure and remained impaired throughout the rewarming condition (Muller et al., 2012). However, there were no significant differences for the Executive Maze Task. These findings suggest that cold exposure negatively impacts both attention and working memory, while there is no effect between cold exposure and spatial memory. When interpreting these results, it is important to note that the study focused on a very small sample size ($n = 10$) limited to only male participants. However, the methodological design shows strong development with the use of the Integneuro™ battery that has been shown to be both a valid and reliable instrument throughout previous literature.

This same methodology also has been used for studies involving mixed gender samples. Hartley and McCabe (2001) examined how cold exposure may affect cognitive performance in twenty (10 women, 10 men) participants from a university (mean age:

21.75 yrs). All volunteers were required to complete a physical activity readiness questionnaire (PAR-Q) before participating in the study. Random assignment was used to place the participants into either the control-experimental condition or the experimental-control condition. Temperatures were consistently managed for both the control condition (18° +/- 2°C) and the experimental condition (0° +/- 2°C) (Hartley & McCabe, 2001). Participants were asked to wear a t-shirt, shorts, socks, and athletic shoes for the study. To assess cognitive functioning, the authors chose the Performance Assessment Battery (PAB). One of the measures included on this battery includes a Working Memory Test. This specific measure was originally designed to assess the cognitive functioning of those individuals placed in stressful environments, with divers being a listed example. Once the PAB was administered in the control room, participants were immediately transferred into the environmental chamber. They then were administered the experimental PAB once their body temperatures had reached a defined temperature (35.5° +/- 0.1 C). Subjects placed in the experimental-control condition were immediately placed in the environmental chamber. Once the PAB was completed, participants then then removed from the chamber to be rewarmed.

When examining working memory performance, researchers did not find a gender effect (Hartley & McCabe, 2001). Participants in the control conditions made a significantly higher number of more accurate and correct responses. These findings suggest that the cold exposure significantly impaired working memory performance. This research involved a well-developed methodological design, with researchers investigating a mixed sample and selecting measures that were appropriate for assessing the variables at interest.

In their study of room temperature and cognitive functioning, Lan, Lian, Pan, and Ye (2009) recruited 24 (12 women, 12 men) employed participants with an average age of 25 years. Participants were instructed to wear light clothes and their own undergarments, socks, and shoes. In order to help increase participants' motivation, they were told that they would receive a bonus based on their performance as well as their fixed salary. Lan et al. (2009) examined four different temperatures (19°C, 24°C, 27°C, and 32°C) controlled by an air conditioner. The participants were placed into four groups with six participants assigned to each group. Participants were placed in an office for 40 minutes before the assessment began in order for the subjects to adapt to the temperature of the environment. Nine different measures were used to assess a wide variety of cognitive functions, including Letter Search, Overlapping, Memory Span, Picture Recognition, and Symbol-Digit Modalities. Collectively, these tasks assess attention and learning memory, as well as working memory in relation to visual, spatial, and verbal functioning.

Results from this study indicate that room temperature did not have a significant effect on either accuracy or response time for the specific neuropsychological measures of interest. The accuracy on several of the measures was only slightly impaired under differing temperatures, but the differences were not significant. Accuracy on the Letter Span task, which is a left hemisphere function, peaked at the 24°C room condition. Accuracy on the Overlapping task, which is associated with the right hemisphere functionality, peaked at 27°C. When interpreting these findings, it is essential to note the finger temperature results taken for each of the room temperature conditions. Three of the room conditions (32°C, 27°C, and 24°C) resulted in relatively similar finger temperatures, whereas the participants' mean finger temperature in the fourth condition (19°C) was significantly lower than those in the other three conditions. This finding indicates a potential limitation in that although the room temperatures varied, personal body temperatures did not vary in three of the four rooms. Based on these findings, it is reasonable to say that the performance on these tasks was not significantly improved or impaired over a short duration within the specified temperature range examined for this study.

Instead of focusing on the impact of cold room exposure on cognitive functioning, Baddeley, Cuccaro, Egstrom, Weltman, and Willis (1975) examined the cognitive performance of a sample of divers exposed to cold water environment. Performed at the U.C.L.A. Underwater Research Facility, 14 (no gender provided) divers were recruited. Participants had an average age of 23 years. The facility where the dives were performed measured to be 16 feet deep and 16 feet wide (Baddeley et al., 1975). One important component of this facility was the heating system that allowed researchers to control water temperature. Participants were paired into teams and were required to visit the facility for three occasions, with the first session for a training run and introduction, and the second and third sessions for the experimental procedures. Divers were exposed to two temperatures: half of the participants were assessed in the colder water condition ($M = 4.7$°C, range = 4.4°C to 5.6°C) first, and the remaining half of participants assessed in the warmer water condition (*M* = 25.8°C, range = 23.3°C to 26.7°C) first. Assessments were performed in the facility at a depth of 16 feet. Rectal temperatures were measured for both divers in each pair.

Four different measures were selected by the researchers, with one of them being a Memory Test developed by Friedman and Greitzer (1972). The task includes a passage with six different items and 30 characteristics relating to the story. Researchers investigated both recall and recognition of memory. Recall was assessed by having the participants provide as many facts about each of the six items they possibly could, whereas recognition was assessed by a test of 24 questions related to the passage in which participants responded to each one as either “true” or “false.” The findings of this research report significant impairment for recall and recognition in the cold condition when compared to the control condition. One limitation to this study is that the authors did not include information pertaining to the gender of the participants. The article provides the number of participants, but does not include the number of men and women within the sample.

Collectively, these few studies assessing cognitive functioning and environmental cold exposure do not provide consistent findings. Although most researchers found impairment in working memory associated with cold exposure (e.g., Hartley & McCabe 2001; Lan et al., 2009; Muller et al., 2012), there were mixed findings for spatial and verbal memory as well as attention. These variations may be due to methodological differences, such as varied room temperatures or group comparison vs within-subject analyses.

Kinsbourne's Theory of Functional Cerebral Space

In analyzing how and why cognitive performance may be related to experiences of cold, it is important to consider one of the theoretical contributions of Austrian neurologist, Marcel Kinsbourne. His theory of functional cerebral space states that the brain acts as a diffuse neural network and activation may spread (Foster et al., 2008; Kolb & Whishaw, 2015). In relation to brain functioning, activation in one region may lead to activation or deactivation in another region. However, these differences vary along longitudinal and lateral axes. As for the lateral axis, Donald Tucker (Kolb & Whishaw, 2015) proposed a hemisphere balance model between the left and right regions. Derek Denny-Brown (Kolb & Whishaw, 2015) investigated the longitudinal axis and reported that a mutual inhibition exists between the frontal and parietal regions. Foster et al. (2008) combined these theories to suggest a quadrant model of activation/deactivation, such that when one quadrant is activated, adjacent quadrants are likely deactivated and the opposite quadrant is activated. These ideas may be of importance to understand the impact of cold exposure on other brain functions.

Located in the anterior region of the parietal lobe, the primary somatosensory cortex plays an important role in processing temperature (Kolb & Whishaw, 2015). Also known as the postcentral gyrus, this region consists of Areas 3, 1, and 2 based on Brodmann's cytoarchitectural map. Somatosensation is a process involving one's body surface and other input from that individual's environment. A variation of somatosensation known as thermosensation is designated specifically to processing environmental temperature. When one is exposed to a cold condition, the parietal lobe may be busy with the task of processing the cold, making it unable to focus as much on other functions associated with opposing regions. Based off of the longitudinal model, activation in the parietal region may lead to deactivation in the frontal region, which would be supported by decreased performance on tasks measuring frontal lobe functions. In fact, another aforementioned study (Lan et al., 2009) described similar reasoning in their research; however, they investigated differences in performance on tests associated with the left or right hemisphere using the lateral axis model.

Summary and Purpose of the Current Study

Research has suggested that cold exposure impairs performance for tasks involving working memory (e.g., Hartley & McCabe, 2001; Muller et al., 2012). One study reported faster response times for working memory tasks but also showed a decrease in accuracy for their responses when exposed to cold temperatures (Duncko et al., 2009). Another study suggests that cold exposure may impair performance depending on the given working memory task (Schoofs et al., 2009). On the contrary, some studies indicate that cold exposure may not have a significant negative impact on working memory functioning (e.g., Ishizuka et al., 2007; Lan et al., 2009). Research also has shown mixed findings when examining the relationship between cold exposure and attention. Ishizuka et al. (2007) reported that cold exposure did not impact performance on tasks requiring attention, whereas Muller et al. (2012) found that cold exposure impaired attention. Paul et al. (2010) reported that performance on tasks requiring attention was not affected by the cold after extended exposure. Ishizuka et al. (2007) also reported a negative relationship between cold exposure and performance on a spatial memory task; however, Muller et al. (2012) found that the cold did not have an impact on this area of functioning. Research assessing verbal memory suggests impairment due to cold exposure (Ishizuka et al., 2007). Results have indicated positive effects (i.e., increased accuracy) as well after prolonged cold exposure in polar environments, specifically for recognition memory and learning tasks (Paul et al., 2010). The inconsistent findings in the body of literature may be related to methodological factors. For example, most of the samples were relatively small and some only assessed men. Some of the research also included complicated procedures for performing assessments and the cold pressor stress test. Also, cold exposure has been studied both environmentally (both geographically as well as in confined space) and using cold pressor exposure. These different methods of inducing "cold" may impact cognitive functioning differently. Finally, Kinsbourne's theory of functional cerebral space suggests that when the body experiences cold, brain areas processing that cold sensation will be "busy" and less able to engage in other functional cerebral tasks.

The purpose of the current study was to examine the impact cold exposure due to environmental conditions (room temperature) may have on memory and attention. In comparison to previous projects, this study included a larger sample, including both genders, and employed a within-subjects design. It was predicted that participants would show decreased speed of mental processing and significantly decreased functioning in verbal memory and in auditory attention in the colder condition when compared to the neutral condition. It also was predicted that perception of cold, as measured by the subjective ratings, would be negatively correlated with performance on all cognitive measures.

CHAPTER II

METHOD

Participants

Participants included 30 volunteers from a southeastern university and the surrounding community. Participants included 21 females and 9 males, with a mean age of 24.27 years (range 19-41). Most participants were Caucasian college students, with a few community volunteers also participating. Table 1 provides a summary of the demographic data for the sample. Individuals were recruited from college courses and through word of mouth from the community. Exclusion criteria included a participant experiencing any of the following health conditions due to the potential relationship between these conditions and either the exposure to cold temperatures or memory functioning: Raynaud's disease, hypothyroidism, diabetes, epilepsy, or treatment for any cardiac condition.

Measures

Demographic Form**.** A measure assessing demographic information, such as age, gender, and ethnicity, was used to gather data to describe the sample (see Appendix A).

Hopkins Verbal Learning Test-Revised (HVLT-R; Brandt & Benedict, 2001). The HVLT-R provides a brief assessment for learning and verbal memory. This measure assesses both long-term memory and short-term memory. It includes a list of 12 words that the examiner recites to the participant three times. Participants are asked to recall the words they can remember after each trial. The fourth trial of the HVLT-R takes place approximately 20-25 minutes after the initial trials. The last portion of this measure involves presenting a list of 24 words to the participant (12 words from the original list and 12 distractors) and having them respond “Yes” if the word was on the original list or “No” if the word was not on the original list. .

Benedict, Schretlen, Groninger, and Brandt (1998) administered a different form of the measure across a six-week duration to college students and found that the six forms were equivalent for the recall portion of the assessment. Research also has shown evidence of convergent validity with the HVLT-R and similar measures of verbal short-term memory and long-term memory. Lacritz, Cullum, Weiner, and Rosenberg (2001) reported a .62 correlation on the delayed recall trial between the HVLT-R and the California Verbal Learning Test (CVLT). Results have found the HVLT-R to be a valid and reliable instrument for measuring the aforementioned domains of memory. Alternate lists are available for the HVLT-T; Forms 1 and 3 were used for the current study in the cold room condition and the neutral room condition. The dependent variables for the current study were immediate recall, delayed recall, retention, and recognition.

Paced Auditory Serial Addition Test (PASAT; Gronwall & Sampsom, 1974; Gronwall & Wrightson, 1974; Gronwall, 1977). The PASAT is a serial-addition test used to measure sustained and divided attention, as well as the capacity and rate of information processing (the amount of information that can be handled at one time). For this measure, the participant is asked to listen to the list of numbers presented and to add every two consecutively presented numbers. Materials include a digital recording consisting of 61 random numbers (ranging from 1 to 9). There are two different forms, with each form having two presentation speeds (presentation of stimuli every 3” and presentation of stimuli every 2”) but with each trial utilizing the same 61 digits. Examiners record both correct and incorrect responses with a maximum score of 60 for each trial. The PASAT has a high internal consistency as indicated by the split-half reliability of .90 (Egan, 1988; Johnson, Roethig-Johnson, & Middleton, 1988). McCaffrey et al. (1995) found that test-retest correlations after a 7-10 day duration were reported to be above .90. Form A and Form B of the PASAT (3 second rate) were used in the current study. The dependent variables for the current study were the overall percentage, the number of commission errors, and the number of omission errors.

Benton Judgment of Line Orientation (JLO; Benton, Varney, & Hamsher, 1978). The JLO is designed to assess visuospatial functioning. This measure includes 30 items with each item presenting two lines both originating from a central point that are oriented in different directions. Each item presents a key showing 11 numbered lines all originating from the central point. The participant is asked to choose which of the numbered lines correspond to the two stimulus lines being presented. Scoring procedures include adding up the number of items in which the participant successfully identified both stimulus lines. The maximum possible score for this measure is 30.

Research has found high reliability for usage with adults for the JLO, with internal consistency coefficients ranging from .84 to .91 (Strauss, Sherman, & Spreen, 2006). Benton, Sivan, Hamsher, Varney, and Spreen (1994) reported a test-retest reliability coefficient of .90. Scores from the JLO have positive correlations with subtests from the Wechsler Adult Intelligence Scale-IV (WAIS-IV) specifically utilizing visuospatial processing (Trahan, 1998), providing further evidence of strong psychometric properties for this measure. There are alternate forms of the JLO available. Forms H and V were utilized in the current study.

Symbol Digit Modalities Test (SDMT; Smith, 1991). The SDMT is used as a measure of attention and processing speed. The examiner reads instructions to the participant and presents the test form. For the written version of this measure, the test form includes a coding key located at the top. The top row of the key includes symbols, whereas the bottom row includes numbers that correspond to each of the symbols. The remainder of the page presents rows with only the symbols provided. This task requires the participant to fill in as many of the spaces as possible with the correct corresponding number in 90 seconds.

Research indicates a test-retest correlation of .80 for the written version of the measure (Smith, 1991). Uchiyama et al. (1994) reported that no significant practice effects were determined when the written version of the SDMT was administered once a year for a two-year duration. This finding suggests that the SDMT is a stable measure over longer time periods. Form A and Form B were used for the current study. The dependent variables for the current study were the overall performance and the number of incorrect items.

Spielberger State-Trait Anxiety Scale (STAI; Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983). The design of the STAI utilizes a self-report format in order to measure both state anxiety and trait anxiety. The measure consists of 40 items, with 20 of the items designed to assess state anxiety (level of anxiety at the time of assessment) and the remaining 20 items to assess trait anxiety. Participants rate their state of anxiety using a 4 point scale ranging from 1 = "Not at all" to 4 = "Very Much So" (Julian, 2011). Spielberger et al. (1983) reported relatively high internal consistency coefficients for high school students (.86) and military recruits (.95). For the current study, the State Anxiety scale was included as a potential covariate to control for anxious behaviors that may affect cognition at the time of the assessment.

Objective Body Temperature. An infrared non-invasive thermometer (Simplife, Model No. IT-121) was used to assess body temperature. The thermometer was positioned by the forehead of each participant to get a body temperature reading. This procedure was repeated three times in order to calculate an average body temperature to ensure the accuracy of the readings.

Subjective Measurement of Temperature Experience. A questionnaire designed by Lan et al. (2009) was selected to assess both thermal sensation and thermal comfort reported by the participant. Each construct is measured with a one item Likert-rating. A seven-point Likert scale was chosen to assess the participant's thermal sensation. The question asked, "How hot/cold are you?" The scale included the following ratings: hot (+3), warm (+2), slightly warm (+1), neutral (0), slightly cool (-1), cool (-2), and cold (-3) (Lan et al., 2009). Participants rated their thermal comfort across a nine-point Likert scale, which included the following ratings: comfortable (0), slightly uncomfortable (1), uncomfortable (2), very uncomfortable (3), and limited tolerance (4). On this scale, positive numbers represented the client feeling warm, whereas negative numbers represented the client feeling cold. The question asked, "How comfortable/uncomfortable are you?" These items were used by Lan et al. (2009) to assess subjective experience of cold following exposure to different room temperatures. No psychometric data were reported for these items, however, average responses to both items varied consistently with various room temperature exposures (e.g., cold room exposure resulted in lower thermal sensation ratings). These ratings were used in the current study to assess one's subjective experience of room and body temperature.

Procedure

Informed consent was obtained prior to the testing session (see Appendix B). Each participant was assessed in both of the following conditions: a neutral room temperature condition (70-72°F) and a colder environmental condition (55-60°F). The neutral room's dimensions were 19-by-14 feet. The colder room (14-by-7 feet) was cooled using a window air-conditioning unit (Roper, 110volt, 5000BTU unit). Participants were required to wear a t-shirt, shorts, and athletic footwear during the testing procedures to increase the likelihood of cold experience. All assessments included the HVLT-R, JLO, SDMT, PASAT, STAI-State questions, and the two subjective measures of temperature experience. The order of administration of the tools was counterbalanced to control for potential order effects with the exception of the HVLT-R, which always was administered first to allow sufficient time to conduct the delayed recall tasks. The demographic questionnaire was completed only during the initial assessment phase. An objective measure of body temperature was recorded before the administration of the assessments in both the neutral and colder temperature conditions. Prior to administration of the cognitive tasks in each condition, the participant was in the room for 10 minutes to allow acclimation to the room temperature.

Design

This study employed a within-participants design, comparing performance on each cognitive measure in the colder condition and the neutral condition for each participant. The order of the room condition was randomized.

CHAPTER III

RESULTS

State anxiety was considered as a potential covariate due to the possible association with anxiety and the dependent measures. Correlational analyses indicated that STAI score was not significantly correlated with any dependent measure in the colder condition and was significantly correlated with only the PASAT in the neutral condition. Additionally, a paired samples t-test ($\alpha = .05$) indicated that the mean scores for the STAI were not significantly different between the neutral condition ($M = 35.53$, $SD = 9.31$, $n = 30$) and colder condition ($M = 36.50$, $SD = 9.53$, $n = 30$), $t(29) = -0.66$, $p = .515$, $d = 0.10$. Based on these findings, anxiety was not used as a covariate in the current study.

Descriptive Statistics

See Table 2 for a summary of the means and standard deviations for all dependent measures by condition (neutral and colder).

A one-way RM ANOVA ($\alpha = .05$) was performed to examine if there were significant differences on the perception of cold across temperature. As measured by the subjective rating scales, participants indicated they felt colder, Wilks' $F(1, 29) = 28.31$, $p < .001$, $\eta^2p = .49$, and reported feeling more uncomfortable, Wilks' $F(1, 29) = 17.44$, $p < .001$, $\eta^2p = .38$, in the colder condition than the neutral condition.

As a manipulation check for activation of the parietal area, it was expected that scores on the JLO (a right parietal activity) would be negatively affected when the brain is processing cold. A one-way RM ANOVA ($\alpha = .05$) indicated that scores on the JLO, however, were not significantly lower in the colder condition, Wilks' $F(1, 29) = .472$, $p = .50$, $\eta^2 p = .016$.

It was predicted that participants would show decreased speed of mental processing in the colder condition when compared to the neutral condition. A repeated measures ANOVA was conducted to test this hypothesis, measuring processing speed with the overall score on the SDMT and the SDMT error score. The one-way RM ANOVA ($\alpha = .05$) indicated that the overall scores on the SDMT were not significantly different across temperature, Wilks' $F(1, 29) = .01$, $p = .942$, $\eta^2 p = .000$. This procedure also indicated that the SDMT error scores did not differ across temperature, Wilks' $F(1, 29) = 0.23$, $p = .637$, $\eta^2 p = .008$.

The second hypothesis predicted that participants would show significantly decreased functioning in verbal memory and in auditory attention in the colder condition when compared to the neutral condition. A repeated measures ANOVA was used to test this hypothesis, measuring verbal memory with the HVLT-R scores and auditory attention with the PASAT scores. The one-way RM ANOVA ($\alpha = .05$) indicated that HVLT-R recognition scores were significantly different across temperature, Wilks' $F(1, 29) = 12.99$, $p = .001$, $\eta^2 p = .309$, with the score in the neutral condition ($M = 11.37$, $SD = .89$) significantly higher than that in the colder condition ($M = 10.6$, $SD = 1.40$). Immediate and delayed recall scores on the HVLT-R, however, were similar across temperature condition, Wilks' $F(1, 29) = .31$, $p = .580$, $\eta^2 p = .001$; Wilks' $F(1, 29) = .01$, $p = .910$, $\eta^2 p = .000$, respectively. Retention, as measured by the HVLT-R, also was similar across the neutral and colder conditions, Wilks' $F(1, 29) = .81$, $p = .374$, $\eta^2 p = .027$.

The overall score on the PASAT and the number of omission errors were similar across temperature, Wilks' $F(1, 29) = .86$, $p = .361$, $\eta^2 p = .029$; Wilks' $F(1, 29) = .05$, $p = .834$, $\eta^2 p = .002$. However, the number of PASAT commission errors differed across temperature, Wilks' $F(1, 29) = 4.57$, $p = .041$, $\eta^2 p = .136$, with significantly more commission errors occurring in the colder condition ($M = 6.10$, $SD = 5.07$) than in the neutral condition ($M = 4.63$, $SD = 5.10$).

It also was hypothesized that perception of cold, as measured by the subjective ratings, would be negatively correlated with performance on all cognitive measures. Pearson *r* correlations were calculated to test this hypothesis with both of the subjective temperature items, the HVLT-R scores, PASAT scores, SDMT scores, and JLO score as dependent measures. Tables 3 and 4 present these correlations for the neutral condition and the colder condition, respectively. Only the PASAT commission error score was significantly correlated with the subjective measures of cold perception when placed in the colder condition. These findings were significant for both the "Hot/Cold" and the "Comfortable/Uncomfortable" subjective ratings. None of the other dependent measures were significantly correlated with the subjective measures of cold perception.

CHAPTER IV

DISCUSSION

The purpose of this study was to examine the impact cold exposure due to environmental conditions (room temperature) may have on measures of memory and attention. First, it was hypothesized that participants would show decreased speed of mental processing in the colder condition when compared to the neutral condition. However, there were no significant differences between the colder condition and neutral condition when examining processing speed from the overall score on the SDMT, nor on the SDMT error score. These findings actually are consistent with a few previous research findings (e.g., Lan et al., 2009; Patil et al., 1995). Lan et al. (2009) utilized a computerized version of SDMT in their room temperature study. No significant differences were reported across temperature when looking at both speed and accuracy performance on this measure. In a cold water emersion study, Patil et al. (1995) measured processing speed with the Digit Symbol Substitution test and reported nonsignificant differences between cold water and lukewarm water.

These findings are in contrast, however, to Hartley and McCabe (2001), who reported that participants performed faster and more accurately in the control condition when compared to the cold environment on the Stroop Color-Word test. Other research (Makinen et al., 2006) utilized the SDMT and Digit Symbol measures and found that exposure to the cold was inversely associated with accuracy and efficiency. These inconsistent findings may be due to differences in the methodological design of each study. Hartley and McCabe (2001) and Makinen et al. (2006) used temperatures that were notably colder than those used by Lan et al. (2009) and the present study. The current study may have been nonsignificant when examining processing speed due to the colder room not reaching low enough temperatures to observe these potential effects.

The second hypothesis was that participants would show significantly decreased functioning in verbal memory and in auditory attention in the colder condition when compared to the neutral condition. Some significant findings were noted in this study. The recognition index on the HVLT-R reported that participants performed significantly better in the neutral room when compared to the colder room. Other scores from the HVLT-R (immediate, delayed, and retention) were similar across temperature condition. When reviewing the literature discussing verbal memory, some research has supported the findings of the present study. Ishizuka et al. (2007) found significantly poorer performance on a measure of verbal memory (CVLT) when exposed to the cold pressor test. Hartley and McCabe (2001) found similar findings in their research specifically for recognition. They reported significantly more accurate responses when exposed to the control condition than the cold condition. Baddeley (1975) found a borderline difference of recognition on a verbal memory measure. However, in contrast to the present study, they reported significantly worse performance when measuring retention in the cold condition. Schwabe and Wolf (2010) assessed verbal memory and reported that recognition was impaired after a 24-hour delay when participants learned the list of words in the cold pressor condition. Their findings for delayed recall reported significantly fewer words were remembered in the cold pressor condition, which was opposite of what the present study suggested. Makinen et al. (2006) reported poorer performance in the cold environment on a recall task.

As for auditory attention, the PASAT overall score and omission error score also were nonsignificant; however, participants made significantly more commission errors when performing in the colder condition. Other studies have utilized different measures of attention. For instance, Muller et al. (2012) selected a Digit Span task and found significantly poorer performance when exposed to the cold. Another study (Lan et al., 2009) reported that temperature did have some effect on speed and accuracy on a Number Calculation measure. However, Paul et al. (2010) reported that performance on the Attention and Concentration test of the PGI Memory Scale was similar throughout prolonged exposure to the cold.

The findings related to verbal memory and auditory attention may be explained by Kinsbourne’s theory. When the participants are exposed to the cold, the area of the brain for processing the cold (e.g., parietal lobe) may be “busy” with that task, so its focus is not on other cerebral functions. Therefore, other parietal tasks, such as the JLO, would be expected to be affected. Applying Denny-Brown’s theory of activation/deactivation along the longitudinal axis, activation of the parietal lobe (cold processing) would deactivate the prefrontal cortex and its association with impulsivity (Kolb & Whishaw, 2015). If the frontal regions are deactivated, then the participants would be less capable of controlling their impulsivity and would be more likely to blurt out responses without thinking them through. Based off of the quadrant model (Foster et al., 2008), activation in the parietal lobe may result in deactivation in the frontal lobe, which could be a potential explanation for the poorer performance in the colder exposure as a response to a loss of control over impulsivity.

Finally, it was hypothesized that perception of cold, as measured by the subjective ratings, will be negatively correlated with performance on all cognitive measures. Only the PASAT commission error score was significantly correlated with the subjective measures of cold perception when placed in the colder condition. It was found that participants were more likely to make commission errors the colder and more uncomfortable they felt in the colder condition. The subjective ratings of the current study were based off of the ones utilized by Lan et al. (2009). In their research, they reported that participants felt most comfortable and neutral in the room conditions when the temperature was around 25°C. The subjective ratings indicated that 80% of the sample rated themselves as "comfortable cool" or "comfortable warm" around 24°C and 27°C. The findings in the current study also may be explained by the changes with impulsivity. Perception in general is associated with posterior regions of the brain. As mentioned previously, the longitudinal model may apply to this hypothesis as well since perception also is associated with the posterior portion of the brain.

Limitations and Future Directions

This study reports interesting findings in regards to potential connections between aspects of memory and attention and cold exposure. However, there are a few limitations. First, this study utilized a small sample size ($N = 30$), although it was larger than those in previous studies. Another limitation is the lack of diversity, with the sample consisting of students and volunteers from the middle Tennessee region who were predominantly

Caucasian and currently enrolled in college or graduate school or who were college educated. Another limitation may be that the current study did not assess left parietal functioning. As previously stated, the JLO is a measure of right parietal functioning. However, since the current study did not include a left parietal task, researchers cannot conclude if it would report any effects on cognitive performance. There also may have been regional differences that the current study did not address. These regional differences may have been important for interpreting the subjective perception of cold. Procedurally, the temperatures in the colder condition may not have been low enough to affect cognitive performance. Due to limitations in resources, the colder room was maintained at 55-60°F, whereas the neutral room was 70-72°F. A majority of the findings in this study were nonsignificant; however, these results may be because the discrepancy between the colder and neutral temperatures was not large enough to observe greater differences on testing performance, as seen in other aforementioned research. Also, although the room temperatures were different across conditions and the participants rated the colder room as more uncomfortable, the objective body temperatures of participants were nonsignificantly different between neutral and colder conditions. It should be investigated to determine if a change in body temperature as a function of cold exposure is a necessary factor to negatively affect cognitive performance

Despite these limitations, interesting findings pertaining to memory and attention were examined. The relationship between the speed of mental processing and cold exposure was not supported. The HVLT-R recognition task and number of commission errors on the PASAT were significantly related to cold exposure, suggesting that a specific skill associated with these measures may be involved. The PASAT commission errors score was the only measure found to negatively correlate with the subjective ratings of cold perception. Future research should utilize a greater sample size with more diversity among participants. It would be interesting to replicate the current design but with creating a greater discrepancy between the colder and neutral temperatures. Future designs may want to assess impulsivity more directly because frontal lobe functioning seems to be particularly vulnerable to deactivation as a function of colder exposure. Future research also should assess regional differences as well as include a measure of left parietal functioning due to the aforementioned limitations. Another interesting feature would be to examine differences across the lateral axis as well based off of Donald Tucker's model.

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APPENDICES

APPENDIX A

Demographic Form

Please answer each of the following questions.

1. I am _____ years old.

2. I am: _____ Male _____ Female

3. My ethnicity can best be described as (circle one):
    - African American
    - Caucasian
    - Hispanic
    - Other: _______________

4. I am a currently a _____ at MTSU (circle one):
    - Freshman
    - Sophomore
    - Junior
    - Senior
    - Other ____________________

5. I am _______ handed. (circle one):
    - Right
    - Left
    - Both

6. Have you been diagnosed with any of the following conditions: diabetes, epilepsy, hypothyroidism, Raynaud's disease, receiving treatment for any Cardiac disease?

    _____Yes
    _____ No

APPENDIX B

Informed Consent

Principal Investigator: Alexis N. Webb
Study Title: Effect of Cold Exposure on Memory and Attention
Institution: Middle Tennessee State University

Name of participant: ____ Age: ___________

The following information is provided to inform you about the research project and your participation in it. Please read this form carefully and feel free to ask any questions you may have about this study and the information given below. You will be given an opportunity to ask questions, and your questions will be answered. Also, you will be given a copy of this consent form.

Your participation in this research study is voluntary. You are also free to withdraw from this study at any time. In the event new information becomes available that may affect the risks or benefits associated with this research study or your willingness to participate in it, you will be notified so that you can make an informed decision whether or not to continue your participation in this study.

For additional information about giving consent or your rights as a participant in this study, please feel free to contact the MTSU Office of Compliance at (615) 494-8918.

1. **Purpose of the study:**
   You are being asked to participate in a research study because we are interested in investigating the effect of cold exposure on memory and attention tasks.

2. **Description of procedures to be followed and approximate duration of the study:**
   The duration of the study will be approximately 1.5 hours, and assessments will be completed in one session. Participants will be asked to wear a T-shirt, shorts, and athletic footwear during testing procedures. Participants will complete a demographic information form followed by the assessments. We will be doing tests of both learning and memory. You will do some of the tests in room at normal temperature and some in a room that is cold (about 55-60 degrees Fahrenheit).

3. **Expected costs:**
   There are not expected costs to any participants other than your time, which will be about 1.5 hours**.**

4. **Description of the discomforts, inconveniences, and/or risks that can be reasonably expected as a result of participation in this study:**
   Because a primary purpose of this study is to test the impact of cold room temperatures on learning, you will be doing some of the assessments in a cold room while wearing your shorts and t-shirt. The room will be set at 55-60 degrees which is colder than most rooms in homes and buildings. You might feel cold, tingly, and/or shiver while we are in the colder room. That part of the study will take about 30 minutes.

5. **Anticipated benefits from this study:**

a) The potential benefits to science and humankind that may result from this study are that we might be able to identify some ways we are affected cognitively by brief exposure to cold. Future research might then focus on identifying measures that might be taken in order to ensure optimal cognitive performance within cold environments.
b) The potential benefits to you from this study is that you will be contributing to the scientific investigation of these issues.

6. **Alternative treatments available:**
   N/A
7. **Compensation for participation:**
   Participants will receive research credit for PSY 1410 courses offered at Middle Tennessee State University. Participants from other courses may receive extra credit offered at your professor's discretion.

8. **Circumstances under which the Principal Investigator may withdraw you from study participation:**
   Students are eligible to participate unless they meet one of the following exclusion criteria: diabetes, epilepsy/seizure disorder, hypothyroidism, or Raynaud's disease due to potential effects of cold exposure. . All participants must be 18 years of age or older.

9. **What happens if you choose to withdraw from study participation:**
   Participation in this study is strictly voluntary are there are no consequences for refusing to participate or withdrawing from the study at any time in the process. The participants may choose to withdraw from the study at any point.

10. **Contact Information.** If you should have any questions about this research study or possible injury, please feel free to contact Alexis Webb (anw6x@mtmail.mtsu.edu) or the Faculty Advisor**,** Kim Ujcich Ward at (kimberly.ward@mtsu.edu).

11. **Confidentiality.** All efforts, within reason, will be made to keep the personal information in your research record private but total privacy cannot be promised. Your information may be shared with MTSU or the government, such as the Middle Tennessee State University Institutional Review Board, Federal Government Office for Human Research Protections, if you or someone else is in danger or if we are required to do so by law.
12. **STATEMENT BY PERSON AGREEING TO PARTICIPATE IN THIS STUDY**
    I have read this informed consent document and the material contained in it has been explained to me verbally. I understand each part of the document, all my questions have been answered, and I freely and voluntarily choose to participate in this study.

____________________ ____
Date Signature of patient/volunteer

Consent obtained by:

____________________ ____
Date Signature

____
Printed Name and Title

APPENDIX C

Debriefing Form

Dear Participant,

Thank you for your time and cooperation with the study. Your participation will allow us to investigate the possible effect cold exposure may have on cognitive functioning. By taking part in this study, we are able to specifically examine functioning for several domains of memory and attention using the results from the neuropsychological batteries we administered. As suggested by the available literature, we predict that both memory and attention may be impaired when you were placed in the colder condition.

If you have any questions or concerns in regards to the procedures or results of this study, please feel free to contact either Alexis Webb (Principal Investigator) or Dr. Kim Ujcich Ward (Faculty Advisor) using the given contact information below.

Thank you once again for your participation!

Principal Investigator
Alexis Webb
anw6x@mtmail.mtsu.edu

Faculty Advisor
Dr. Kim Ujcich Ward
kimberly.ward@mtsu.edu

____
Participant Signature

____
Date

APPENDIX D

MTSU IRB Approval

Thursday, May 18, 2017

Principal Investigator	**Alexis N. Webb** (Student)
Faculty Advisor	Kimberly Ujcich Ward
Co-Investigators	NONE
Investigator Email(s)	*anw6x@mtmail.mtsu.edu; kimberly.ward@mtsu.edu*
Department	Psychology
Protocol Title	Effect of cold exposure on memory and attention
Protocol ID	17-2241

Dear Investigator(s), The above identified research proposal has been reviewed by the MTSU Institutional Review Board (IRB) through the EXPEDITED mechanism under 45 CFR 46.110 and 21 CFR 56.110 within the category (7) Research on individual or group characteristics or behavior A summary of the IRB action and other particulars in regard to this protocol application is tabulated as shown below:

IRB Action	APPROVED for one year from the date of this notification
Date of expiration	5/31/2018
Participant Size	50 (FIFTY)
Participant Pool	Adult (18 or older) MTSU students
Exceptions	1. Permitted to recruit participants through the SONA System. 2. Conrad Landis and Samantha Hunt are permitted to provide research assistance along with Amanda Fletcher (graduate research assistant).
Restrictions	1. Mandatory signed informed consent. 2. Research assistants who are not listed as co-investigators must meet CITI training requirement consistent with the research team.
Comments	All student investigators listed in this protocol, regardless they are coinvestigators or assistants, must complete "students in research" module under the CITI "Social and Behavioral Research" training course.

This protocol can be continued for up to THREE years (5/31/2020) by obtaining a continuation approval prior to 5/31/2018. Refer to the following schedule to plan your annual project reports and be aware that you may not receive a separate reminder to complete your continuing reviews. Failure in obtaining an approval for continuation will automatically result in cancellation of this protocol. Moreover, the completion of this study MUST be notified to the Office of Compliance by filing a final report in order to close-out the protocol.

Continuing Review Schedule:

Reporting Period	Requisition Deadline	IRB Comments
First year report	4/30/2018	TO BE COMPLETED
Second year report	4/30/2019	TO BE COMPLETED
Final report	4/30/2020	TO BE COMPLETED

Post-approval Protocol Amendments:

Date	**Amendment(s)**	**IRB Comments**
NONE	NONE	NONE

The investigator(s) indicated in this notification should read and abide by all of the post-approval conditions imposed with this approval. Refer to the post-approval guidelines posted in the MTSU IRB's website. Any unanticipated harms to participants or adverse events must be reported to the Office of Compliance at (615) 494-8918 within 48 hours of the incident. Amendments to this protocol must be approved by the IRB. Inclusion of new researchers must also be approved by the Office of Compliance before they begin to work on the project.

All of the research-related records, which include signed consent forms, investigator information and other documents related to the study, must be retained by the PI or the faculty advisor (if the PI is a student) at the secure location mentioned in the protocol application. The data storage must be maintained for at least three (3) years after study completion. Subsequently, the researcher may destroy the data in a manner that maintains confidentiality and anonymity. IRB reserves the right to modify, change or cancel the terms of this letter without prior notice. Be advised that IRB also reserves the right to inspect or audit your records if needed.

Sincerely,

Institutional Review Board
Middle Tennessee State University

APPENDIX E

Tables

Table 1

Demographic characteristics of sample

Characteristic	*N*	%
Gender		
Male	9	30.0
Female	21	70.0
Ethnicity		
African American	5	16.7
Caucasian	23	76.7
Hispanic	1	3.3
Other	1	3.3
Education		
Freshman	0	0.0
Sophomore	3	10.0
Junior	7	23.3
Senior	10	33.3
Other	10	33.3
Handedness		
Right	25	83.3
Left	5	16.7
Both	0	0.0

Table 2

Descriptive statistics for the neutral condition and colder condition

	Neutral Condition		Colder Condition	
Measure	*M*	*SD*	*M*	*SD*
HVLT- IR	26.73	3.75	27.13	4.75
HVLT- DR	9.37	1.94	9.40	2.28
HVLT- Retn	90.92	13.66	88.26	15.41
HVLT- Recog	11.37	0.89	10.60	1.40
PASAT	77.28	18.41	75.17	16.22
PASAT- CE	4.63	5.10	6.10	5.07
PASAT- OE	9.00	7.96	8.80	6.08
JLO	24.33	4.35	24.00	4.81
SDMT	53.33	11.03	53.17	6.36
SDMT- ER	0.87	2.29	0.70	1.34
STAI	35.53	9.31	36.50	9.53
H/C	0.63	0.77	1.77	0.68
C/U	0.23	0.43	1.10	1.03
Obj. Temp	98.00	0.70	96.88	0.76

HVLT- IR = HVLT Immediate Recall. HVLT- DR = HVLT Delayed Recall. HVLT- Retn = HVLT Retention. HVLT- Recog = HVLT Recognition Discrimination Index. PASAT- CE = PASAT Commission Errors. PASAT- OE = PASAT Omission Errors. SDMT- ER = SDMT Errors. H/C = Subjective Hot/Colder Rating. C/U = Subjective Comfortable/Uncomfortable Rating.

Table 3

Correlations between dependent measures within neutral condition

	2	3	4	5	6	7	8	9	10	11	12
1. HVLT- IR	.57**	-.02	.30	.56**	-.31	-.58**	.31	.33	-.10	-.30	-.24
2. HVLT- DR	--	.73**	.50**	.47**	-.25	-.53**	.48**	.51**	-.18	-.05	.10
3. HVLT- Retn		--	.37**	.12	-.02	-.15	.39*	.43*	-.26	.16	.15
4. HVLT- Recog			--	.01	.17	-.12	.07	.18	.09	-.05	-.14
5. PASAT				--	-.75**	-.91**	.49**	.42*	-.26	-.26	-.16
6. PASAT- CE					--	.40*	-.51**	-.31	.22	.19	.04
7. PASAT- OE						--	-.35	-.38*	.22	.24	.20
8. JLO							--	.32	-.49**	-.01	.01
9. SDMT								--	-.31	-.14	-.02
10. SDMT- ER									--	.21	.35
11. H/C										--	.48**
12. C/U											--

*p < .05. **p < .01.

Table 4

Correlations between dependent measures within colder condition

	2	3	4	5	6	7	8	9	10	11	12
1. HVLT- IR	.71**	.24	.46*	.29	-.21	-.29	.18	.21	-.17	.09	-.16
2. HVLT- DR	--	.78**	.78**	.25	-.18	-.25	.31	.23	.05	-.00	-.28
3. HVLT- Retn		--	.64**	.24	-.19	-.22	.34	.18	.22	-.02	-.21
4. HVLT- Recog			--	-.02	.12	-.06	-.03	.08	.15	-.10	-.28
5. PASAT				--	-.85**	-.90**	.52**	.46*	-.05	.32	.16
6. PASAT- CE					--	.52**	-.56**	-.23	.05	-.48**	-.40*
7. PASAT- OE						--	-.36*	-.55**	.04	-.11	.08
8. JLO							--	.30	-.29	.31	.26
9. SDMT								--	.12	.11	.03
10. SDMT- ER									--	.11	-.03
11. H/C										--	.63**
12. C/U											--

*p < .05. **p < .01.