The Effects of High and Low Arousal on Memory Consolidation

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Glossary and Abbreviations

LTM: long-term memory – memory storage system, divided into declarative memory and procedural memory, that enables memories to be stored and retrieved from hours to years following original learning (APA, 2019).

STM: memory that can be recalled for a period of 10-30 seconds after learning (APA, 2019).

WM: memory that is retained and accessible to allow for learning, reasoning and comprehension (APA, 2019).

CPT: abbreviation for cold pressure test (APA, 2019).

SCPT: abbreviation for social cold pressure test (APA, 2019).

Stress: - physiological or psychological response to internal or external stressor. Can be behavioural response or body system response (APA, 2019).

Arousal: - physiological activation or cortical responsiveness associated with sensory stimulation. Related to a person's appraisal of physical intensity of an event which can either enhance or impair performance (APA, 2019).

Abstract

Empirical evidence shows that physiological or psychological arousal can influence memory performance. Methodological differences, such as different memory tasks, make it difficult to determine how these processes work. Therefore, in this study we investigate how heightened and lowered arousal affect memory of the same stimuli. We compared the effects of heightened and lowered arousal with a control condition on memory consolidation. In a mixed-factor design, participants (N=100) took part in three experimental conditions. Following a visual word/picture memorisation task, participants either immersed their left hand in an ice-bucket for 3 minutes (Heightened arousal), listened to a guided meditation for 5 minutes (Lowered arousal), or went directly to the retention interval (Control). Subsequently they attended two testing sessions, 35 minutes following encoding and one week later. Our results showed that performance of the participants in the heightened arousal condition was significantly better than control on both testing sessions, and that lowered arousal condition was significantly better than the Control in the second testing session. These results contribute towards arousal on memory consolidation and point towards possible mechanisms involved in this process.

Keywords: Arousal, memory, consolidation.

Effects of Arousal on Memory Consolidation

Empirical evidence shows that both high and low physiological and psychological arousal can influence memory performance (Mather, 2007). Moreover, conflicting findings on the effect of arousal on long-term memory make it difficult to determine how different sources of arousal engage different memory processes. Some of the conflict may come from different methodologies, for example, some studies employ arousing stimuli such as aversive pictures (Wiemers, Hamacher-Dang, Yonelinas, & Wolf, 2019), whereas other studies use emotional word stimuli (Zoladz, et al., 2010) or neutral stimuli (Luethi, Meier, & Sandi, 2009). Further, arousal may not be inherent in the stimuli, but can be moderated by interventions such as the cold pressor test (CPT) (McCullough & Yonelinas, 2013) or mindfulness (Roberts-Wolfe, Sacchet, Hastings, Roth, & Britton, 2012). There is also some debate on whether personality affects arousal (Eysenck, 1976). Therefore, this study aims to control for some of these variations by comparing how heightened and lowered arousal levels during consolidation impacts on memory performance in one study that incorporates the same memory task throughout. The results of this study will enable extra insight into how manipulating arousal may change memory performance for the same stimuli.

Effects of Arousal on Memory

Empirically there have been several theories of arousal although several of these link arousal and emotion. The James Lange theory posits that events cause arousal, leading to physiological changes which are then interpreted as an emotion (Gross, 2009). The Cannon Bard theory suggests that emotion and arousal occur at the same time and are independent of physiological changes (Gross, 2009), and Schacter-Singer theory goes further to add that arousal together with cognition of recognising the emotion determines emotion (Gross, 2009). Further, Easterbrook (1959) investigated emotional arousal, arguing that high levels of emotional arousal lead to narrowing field of attention, thereby only allowing for central information to be memorised, and not the peripheral information. Linking emotion and arousal together with one not being able to occur without the

other may be a limiting approach in distinguishing and isolating the effect of arousal on consolidation as both are different concepts and have been shown to activate different brain regions. However, with regards to arousal, Easterbrook (1959) partly supports the Yerkes Dodson law (Yerkes & Dodson, 1908).

Yerkes Dodson law (Yerkes & Dodson, 1908), often remembered by its inverted u shape, partly explains the phenomenon where arousal increases memory performance up to a point, but after that point memory performance decreases, thereby suggesting an optimum amount of arousal being beneficial for memory, but too much arousal being detrimental to memory. Easterbrook (1959) suggests that high arousal impairs memory for peripheral information, supporting a link between arousal and attention processes. Additionally, Sharot and Phelps (2004) found a link between heightened arousal and attention. Using neutral and arousing words presented either centrally or peripherally they found that arousing words were remembered for longer than neutral words regardless of where in the visual field they were presented.

There is conflicting evidence on how memory processes are influenced, depending on where in the memory process the arousal takes place and the type of stimuli used. It is important to note that memory has been tested in studies with stimuli containing inherent arousal or emotion such as pictures or words and this has been compared to memory of neutral stimuli. Moreover arousal can also be present when visual stimuli is neutral and arousal is manipulated through intervention of pain or exercise. However it should be noted that these are two different types of arousal – psychological and physiological and that these may influence brain activity differently as physiological arousal may impact cortisol, heart rate and oxygenation levels. Arousal is associated with consolidation processes. Empirically, there have been several theories on how arousal affects consolidation.

Effects of Arousal on Consolidation

More recently there have been studies investigating the consolidation phase of memory which may be helpful in trying to ascertain how arousal after learning influences long-term memory. Consolidation, as suggested by Muller and Pilzecker (1900) (Dudai, 2004) is a process that occurs after learning and several studies have shown that an optimum amount of arousal after encoding enhances memory over time, anywhere between 30 minutes and one week (Nielson & Correro, 2017). Both higher emotive and arousing stimuli have been shown to enhance memory (Shields et al., 2017). Although empirical literature often combines emotion and arousal under one umbrella, studies that are more recent suggest that these two types of stimuli can be processed independently from each other (Mather, Clewett, Sakiki, & Harley, 2016).

Long-term memory consolidation of explicit information has been shown to require several brain areas. McGaugh (2000) suggested that consolidation is hippocampal dependent enabled through stress hormones and allowed for amygdala activation for emotional stimuli. More recently it has been suggested that the hippocampus processes and sends memory to other parts of the cortex including the pre frontal cortex (Vogel & Schwabe, 2016) and is involved in consolidation (Vogel & Schwabe, 2016) and retrieval processes (Vogel & Schwabe, 2016). Furthermore, if stimuli have emotional content, then the amygdala is also active (Vogel & Schwabe, 2016). Further, Genzel and Wixted (2017) suggested that when memory is tested soon after post learning, arousal was primarily more likely to engage hippocampal processes, whereas when memory is tested days later when sleep has occurred, retrieval was more likely to engage further cortical processes (Nielson & Correro, 2017). Thereby suggesting a process of consolidation between the hippocampus, prefrontal cortex and other cortical areas. Additionally, with improvement in brain imaging studies, neurocognitive studies further support that the amygdala, hippocampus and prefrontal cortex areas to be most associated with memory (Vogel & Schwabe, 2016), together with the Locus Coeruleus and its neurotransmitter norepinephrine for arousal influenced memory (Mather et al., 2016).

Neurotransmitters vastly influence memory processes. Recently, norepinephrine is suggested to be a main neurotransmitter for arousing stimuli influencing memory performance (Mather et al., 2016). Projected from the Locus Coeruleus; a small area on the upper pons, to most major brain areas, norepinephrine activates or deactivates areas involved in memory by creating hotspots through glutamate release– with hotspots enabling enhanced consolidation, and information next to hotspots being inhibited and therefore memory for these being impaired. Mather et al. (2016) suggests that GABA enables more activation in certain brain areas, which create hotspots and enable memory to be consolidated, whereas areas next to the hotspots inhibit memory. Mather et al. (2016) reviewed how memory is enhanced by arousal in the consolidation phase and suggest that arousing stimuli are consolidated through arousal mechanisms which enable the Locus Coeruleus activation of norepinephrine producing hotspots which enables better memory for high priority information. This seems to support the Yerkes Dodson theory (Yerkes & Dodson, 1908) that optimum arousal enhances memory whereas a lot or not enough impairs memory. Further, a review by Absolon, Muller, and Javadi (in preparation) suggests a new model for memory wherein the Locus Coeruleus and its neurotransmitter norepinephrine is central to the independent consolidation of arousing stimuli. Although arousing stimuli have been shown to alter the release of neurotransmitters, they have also been shown to alter the hormonal system of the brain, in particular the stress hormone cortisol which has been used to measure stress response to arousing stimuli (Schwabe, Bohringer, Chatterjee, & Schachinger, 2008).

Interventions

Physiological stress response can be used to manipulate psychological arousal. Sensory stimuli originate response to the brain via the nervous system which in turn activates release of neurotransmitters and hormones in the brain (Gross, 2009). The parasympathetic response system is active when the body is in a resting state, whereas when threatened by danger and stressed, the sympathetic response system takes over (Gross, 2009). It is this change from parasympathetic to sympathetic that we are manipulating in an experiment where we induce sudden pain, such as the

cold pressor test. This change sends messages to the brain so that it may release neurotransmitters, of which Glutamate, GABA, and norepinephrine together with cortisol are important for memory formation and consolidation (Mather et al., 2016).

Empirical evidence generally shows that for encoding, stress enhances memory dependent on when the stressor is administered prior to learning (Zoladz, et al., 2010). Further, stress post encoding has been shown to decrease both free recall and recognition long-term memory (Quaedflieg, Schwabe, Meyer, & Smeets, 2013), and this has been linked to stress causing higher cortisol levels which is generally related to impaired memory (Buchanan, Tranel, & Adolphs, 2006). Additionally, post encoding stress in the same context as learning phase leads to an increase in memory (Shields et al., 2017). Therefore, manipulating stress response enables a way to measure how stress arousal affects memory. These results further suggest that a more comprehensive investigation is required into how intervention induced stress is linked to physiological and psychological arousal, and how this in turn affects memory processes.

Cold Pressor Test (Ice bucket).

One popular method to heighten arousal through the physiological stress response is the Cold Pressure Test (CPT), or the Social Cold Pressure Test (SCPT). The SCPT involves placing a hand in a bucket of iced water for 3 minutes while being videoed, whereas the cold pressure test does not include the video. The methodology of CPT typically measures cortisol levels enabling experimenters to compare changes in cortisol levels to changes in memory performance. CPT generally elevates cortisol levels. However, results have been inconsistent, depending on whether the stressor is administered before during or after encoding and whether the stress and subsequent memory test are completed in the same room (context). For example, Schwabe et al.(2008) found that pre encoding stress enhanced free recall of neutral words irrespective of cortisol response, whereas negative words but not positive words were enhanced by cortisol response. Thereby suggesting that stress at encoding, in the same context pre encoding has differing influences on

memory. Whereas, CPT experienced after encoding has been found to enhance memory for emotionally arousing stimuli, but not for neutral stimuli, thereby supporting that stress after encoding, interacts with the arousal of the stimuli and assists successful memory consolidation (Cahill, Gorski, & Le, 2003). Further, Sazma, McCullough, Shields and Yonelinas (2018) found an increase in recognition memory when the stressor and test are done in the same room (context) for both negative and neutral images with no gender differences, concluding that stress enhances ongoing encoding, thereby helping consolidation.

However, consideration should be given to how soon after encoding the stressor is given as this seem to make a difference to memory. Schwabe and Wolf (2014) found no enhanced memory for neutral or negative words when CPT was given 1 day after encoding and recognition test given immediately, but found impairment when test was performed at 25 and 90 minutes after stressor was given, suggesting that heightened cortisol levels impaired memory. Moreover, it is not just cortisol levels that can change with CPT, other physiological changes take place which could in turn affect memory processes.

Therefore, if high stress is assumed to heighten attention which enhances memory, but also heighten cortisol which may impair memory, then there is an argument to suggest that memory may be enhanced by heightening attention, whilst controlling for lower cortisol levels.

Meditation.

Meditation is a mental practise that is one way to lower stress, whilst maintaining high attention levels (Basso, McHale, Ende, Oberlin, & Suzuki, 2019). Mindfulness is a form of meditation where the person is encouraged to concentrate on one thing, often the breath, as a way of finding calm and relaxation of the body and mind. This has garnered interest more recently, with investigations into how it influences both working and long-term memory, and the effects of differing lengths of intervention.

Empirical evidence generally seems to show that mindfulness improves working memory as well as autobiographical memory (Lao, Kissane, & Meadows, 2016). The improvements to working memory have been supported by (Banks, Welhaf, & Srour, 2015) who suggested that mindfulness training enhances attention, which in turn decreases mind wandering, thereby decreasing stress related working memory impairments. Further**,** Singh, Sharma, and Talwar (2012) found that short term meditation saw a decrease in GSR and improvement of reaction time, but that long-term meditation also saw improvements in cognitive function scores. Additionally, Jensen et al. (2011) and Quach et al.(2016) found significant improvements in working memory capacity over a 4-week period mindfulness condition, when there was no difference in stress or anxiety between groups.

Furthermore, mindfulness, compared to mind wandering produced increased retrieval of neutral words (Rosenstreich & Ruderman, 2017). Mindfulness has also been shown to be more effective than other types of meditation.

Jensen, Vangkilde, Frokjaer, and Hasselbalch (2011) found that selective attention, conscious perception and visual working memory capacity were all enhanced in the mindfulness-based stress reduction group when compared to the non-mindfulness stress reduction group. This would seem to hold even when mindfulness is compared to hatha yoga (Quach, Jastrowski Mano, & Alexander, 2016). However, although individually it would seem that mindfulness helps memory through enhancing attention processes, a review by Lao et al. (2016) did not support this hypothesis and found that improvements were only robust in working memory, autobiographical memory, cognitive flexibility and meta-awareness. Moreover, there is an argument that because mindfulness enhances working memory, this could in turn enhance long-term memory (Brown, Goodman, Ryan, & Analayo, 2016) and more recent studies have also found that long-term memory may be positively influenced through mindfulness interventions.

Mindfulness has also been shown to enhance long-term memory, especially recognition memory, although it does seem to depend on where in the learning process the mindfulness takes

place. Lloyd, Szani, Rubenstein, Colgary, and Pereira-Pasarin (2016) found that 3 minutes of mindfulness before recognition memory test produced less false alarms on a recognition test, compared to 3 minutes of mindfulness prior to encoding, suggesting that short term mindfulness is more beneficial between learning and test. This was in contradiction to Bonamo, Legerski, and Thomas (2015) who found mindfulness before encoding enhanced memory. However, it could be argued that the difference in results could be explained by the different methodologies used as Lloyd et al. (2016) included new pictures mixed with old pictures in the test, whereas Bonamo et al. (2015) did not. Therefore, method of testing and where in the learning procedure mindfulness most influences memory is inconclusive. Further, the amount of mindfulness practice is also important.

Empirical evidence does seem to indicate that more practice correlates with improved memory. When comparing long term meditators to non-meditators on free recall memory of an aurally presented word list, Lykins, Baer, and Gottlob (2012) found that long term meditators exhibit better memory than non-meditators, thereby supporting that long-term meditation of on average 6 years should enhance memory. Further, Ching, Koo, Tsai, and Chen (2015) found that spatial working memory was improved over an 18-week mindfulness weekly intervention. Additionally, Basso et al. (2019) found that 8 weeks, rather than 4 weeks of daily guided meditation had a more effect of decreasing negative mood, anxiety, and enhancing attention: all things that are associated with enabling a better working memory. Expertise in mindfulness has also been found to influence long-term memory where long-term meditators exhibited better recall memory of aurally presented words than non-meditators, thereby supporting that long-term mediation of on average 6 years should enhance memory (Lykins et al., 2012). Therefore, it seems the length of mindfulness intervention is the key to whether memory is enhanced or not.

However, many studies do not allow for expertise in meditation, and high arousal studies often include a CPT which is only 3 minutes intervention time. Therefore, to be able to compare arousal levels, it may be important to investigate how a short-term intervention of mindfulness after

learning effects long-term memory. Further, moderating factors require investigation as empirical evidence suggests that these may be associated with arousal.

Moderating Factors

Effects of personality.

Eysenck (1976) found that introverts and extroverts exhibited different baseline arousal levels. He suggested that extroverts have a lower baseline arousal and thereby seek stimulating environments to heighten that arousal level. Whereas, introverts have a naturally higher baseline arousal level and seek calm environments to lower it. Further, it has been suggested that when introverts are in a stimulating environment, they experience mental fatigue and inhibited concentration (Belojevic, Slepcevic, & Jakovljevic, 2001).

More recent research by Larsen and Buss (2008) has suggested that it is not a difference in baseline arousal, but rather that extroverts and introverts have different arousal mechanisms – with extroverts experiencing higher arousal levels than introverts in stimulating environments. This supports research by Campbell and Hawley (1982) who found that introverts like quiet library areas, whereas extraverts prefer the noisier library areas.

It may not be just personality differences that account for the confounding results in arousal studies. One such confound could be that psychology research relies predominantly on psychology students, aged between 18 and 31 years, mainly female and therefore menstrual cycle and hormonal contraceptive use in females compared to males could be confounding the results.

Effects of menstrual cycle.

Andreano and Cahill (2006) found that sex of a participant does make a difference in studies which involve stress arousal and memory performance. Although cortisol response was significantly raised in both sexes, memory was found to be better in males. This supported previous research that found cortisol response did not differ between males and females (Kudielka &

Kirschbaum, 2005), thereby leading Andreano and Cahill (2006) to suggest that menstrual phase should be considered. Further, Shields et al. (2017) in a review of 6216 participants within 113 studies found that men have a higher cortisol response than women who were taking hormonal contraceptives.

Women's menstrual cycle has several phases; follicular – day 1-13 which is high in oestrogen, ovulation phase on day 14, luteal phase on days 15 to 29 which is when progesterone is high, however this is also dependent on length of cycle. Further, menstrual cycle and hormonal contraceptives have been shown to alter arousal levels in females.

Andreano, Arjomandi, and Cahill (2008), found that there was no difference in memory in any menstrual phase, but that cortisol levels did differ, especially that cortisol was higher in the mid luteal phase and suggested that glucocorticoid effects can influence memory when they are modulated by sex hormones. Further, in a review Andreano and Cahill (2009) found that women in the early follicular phase performed the same as men in some tasks, however they suggested that this is task dependent, and suggested that differences in memory performance could be mediated by interactions between stress arousal and sex hormones. Additionally, Kuhlmann and Wolf (2005) compared differing menstrual phases in terms of stress effects on memory and found that on consolidation there was a significant difference between stress induced cortisol and narrative recall with an enhanced recall in the mid luteal phase and impaired recall in the early follicular phase. Whereas, during retrieval, cortisol levels impaired retrieval during mensis and luteal phases, but not in oral contraceptive users. Thereby suggesting that cortisol effects on memory were different depending on whether it was consolidation or retrieval. Therefore, not only menstrual phase but also oral contraceptives could be confounding memory and arousal results.

Effects of hormonal contraceptives.

Schwabe and Wolf (2010) found that women taking hormonal contraceptives had a lower overall cortisol response, therefore although this did not stop cortisol response to stress, it may be

lower because of a lower baseline level. Further Sheilds et al. (2017) found that there was a difference in stress amongst women who were taking hormonal contraceptives and women who were not taking hormonal contraceptives. They also found that those with high progesterone during luteal phase of the menstrual cycle had a higher stress response.

Physiological measurement

Neurological studies investigate brain activation using fMRI which measures blood oxygenation levels. Although some behavioural studies have measured how heart rate and oxygenation levels manipulated by arousal effect memory little has been investigated in this area. Evidence currently suggests that heart rate is found to enhance memory consolidation, with high heart rate predicting enhanced memory for recognition of happy or sad faces one day after encoding (Larra, et al., 2014).

Empirical evidence is mixed as to how arousal can enhance or impair memory. There have been many investigations, but none have employed the same task and stimuli for a direct comparison between high and low arousal. Therefore, this study will use a between participants design to directly compare how high or low arousal influences memory of neutral stimuli. This study will also look at how personality, menstrual phase and hormonal contraceptives influence memory in these conditions. We hypothesise that

1. Memory performance will be enhanced in the high arousal condition, with greater improvement for extraverts compared to introverts.
2. Memory performance will be enhanced in the low arousal condition, with greater improvement for introverts compared to extroverts.
3. Memory performance will be moderated by hormonal contraceptives and menstrual cycle.

Method

Participants

Female psychology students from the University of Kent (N=100, age range 18-24 years, mean age 19.40 years), participated as part of the research participation scheme in return for course credits. All participants were fluent in English. All participants read the information sheet detailing the procedure of the study, gave their written informed consent, and were fully debriefed at the end of the study. The protocol of the study has been approved by the local ethics committee in the School of Psychology at University of Kent.

Materials

Measurements

Personality Questionnaire

HEXACO personality questionnaire. Please see Appendix A. All participants filled out the HEXACO personality questionnaire (honesty-humility, emotionality, extraversion, agreeableness (versus anger), conscientiousness, openness to experience) to assess their personality traits in particular introversion or extraversion,

Contraceptives/cycle questionnaire

A contraceptives questionnaire to inquire about the contraception method use, and menstrual phase at the time of encoding, which was used for data analysis. Please see Appendix A.

Physiological Measures

A Contec pulse oximeter CMS 50D+ heart rate monitor (BLYL LTD) was attached to the index finger of the left hand of the participant throughout the encoding, intervention and retrieval. Prior to the beginning of the encoding task, a 2-minute baseline measure of heart rate and SpO2 was measured.

Stimuli

A set of 160 stimuli were collected, of which 80 were randomly selected for the encoding phase and 80 as foil in the retrieval phase. The stimuli consisted of everyday objects such as bicycle, table and gate. All objects were neutral with no particular reference to ice-bucket or meditation. They were collected by search in Google Images, all with white background. A sample of these images is shown in Figure 1. Stimuli shown in each condition were unique to that condition. The stimuli were presented using the MATLAB program.

Interventions

Meditation

Participants in the guided meditation condition were instructed to listen to a 5-minute guided Eluned Gold meditation (https://www.bangor.ac.uk/mindfulness/audio/index.php.en). It was played through headphones. The mediation was a guided breathing exercise, so that it catered for those participants who had not meditated before.

Ice Bucket

Participants in the ice bucket condition were instructed to keep their hand in the bucket of water and ice at a temperature near zero degrees Celsius for the entire three minutes if possible.

Procedure

Participants were invited into the lab and randomly allocated to one of three conditions: Low arousal (guided meditation), High arousal (ice bucket) or Control (no intervention). They were advised of the condition via the information sheet presented at the beginning of the study. They sat in front of a computer screen that presented two blocks of 40 different pictures depicting everyday objects together with congruent word in random order. For example, a picture of a walnut was presented with the word ‘walnut’ underneath, as shown in Figure 1. Please see below for further details of the stimuli. Each word-picture pair was presented for a duration of 1 second followed by a

3-second fixation cross on the middle of the screen. The next stimulus was presented immediately afterwards. Participants were instructed to memorise the stimuli for a later recognition task.

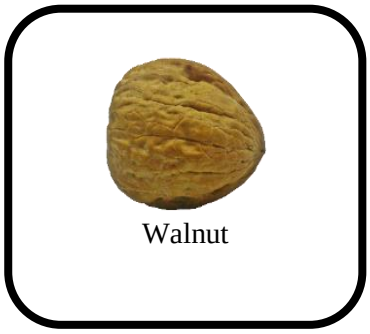


Figure 1. Presentation of stimuli

Immediately following encoding, participants were subjected to one of three interventions: (1) 3 minutes of immersing their left hand in a bucket of iced water, (2) 5 minutes guided mindfulness meditation, or (3) control of no intervention. See Figure 2 for the procedure of the three conditions. Following intervention, or encoding in the case of the Control condition, participants completed online jigsaw puzzles. Following the 30-minute retention interval, participants were given an old/new recognition task (Outcome Measure 1) consisting of 160 stimuli (80 old and 80 new presented randomly). Participants were instructed to respond to the stimuli as quickly and as accurately as possible. Finally, participants took part in the second recognition task (Outcome Measure 2) one week later to investigate their long-term memory performance.

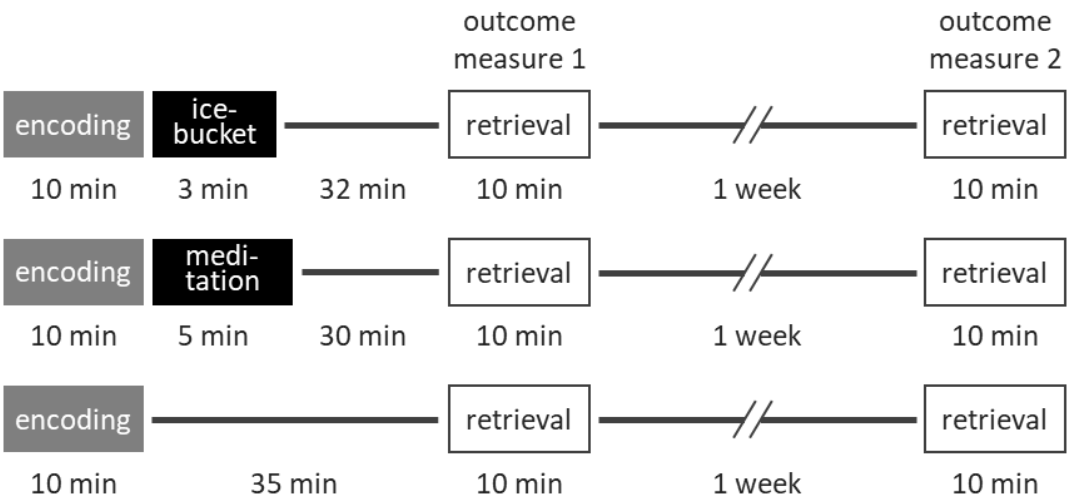


Figure 2. Diagram of the procedure for the three conditions.

Statistical Analysis

Physiological measures of SpO2 and pulse were analysed using false rate discovery rate correction for multiple comparison. To account for response bias, and to distinguish between familiarity associated with the target and distractor items Signal detection theory was used and recognition memory was measured by d'. A mixed factor ANOVA was run to explore the three conditions and two sessions. This was further investigated with independent sample t-tests and a 2x2 mixed factor ANOVA. A mixed factor ANCOVA was run with personality as covariate with further analysis of Mixed factor ANOVA with extraversion as between subject factor. Further post hoc comparisons were run to investigate the effects of extraversion and condition. To investigate menstrual cycle and contraceptive use an ANCOVA was run using menstrual phase as covariate, and a mixed factor ANOVA with contraceptives as a between subject factor.

Results

Analyses focus on physiological measures of heart rate and SpO2, and whether memory was enhanced or impaired by the conditions of ice bucket (high) (N=37) and meditation (low) (N= 31), compared to control (N= 32).

Physiological measures were analysed using paired sample t-tests between baseline and intervention for second by second data. We used false discovery rate (FDR) correction for correction for multiple comparison. This analysis showed an overall significantly higher SpO2 in the High condition as compared to the baseline with no difference in heart rate (see Figure 3). Similar analysis for the Low condition showed no changes in the SpO2, but a significantly lower heart rate (see Figure 4).

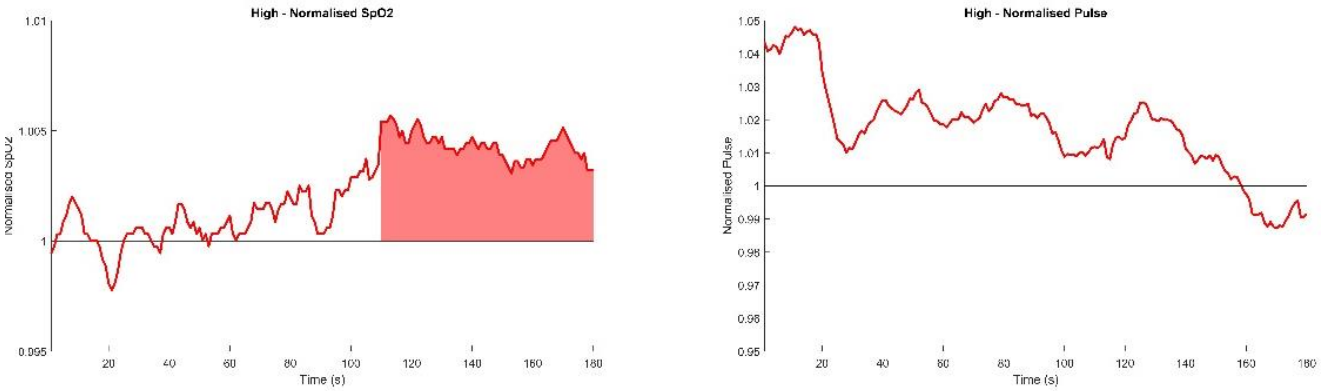


Figure 3. Showing significant change in SpO2 levels during the Ice bucket (High) intervention, but no significant change in pulse level. Shaded area shows significant change compared to the baseline, using false discovery rate (FDR) correction for multiple comparison.

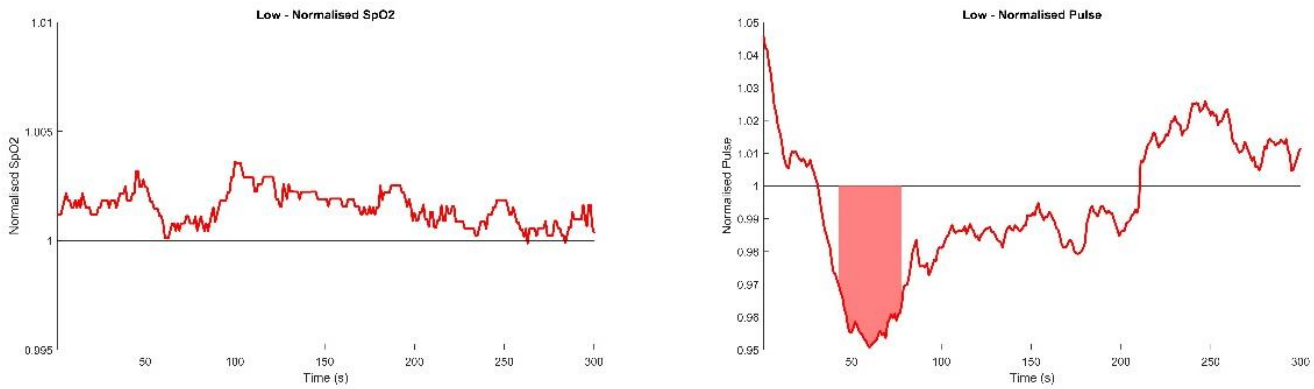


Figure 4. Showing significant change in pulse during the meditation (Low) intervention, but no significant change in SpO2 level. Shaded area shows significant change compared to the baseline, using false discovery rate (FDR) correction for multiple comparison.

These results suggest that the interventions did manipulate the physiological responses in participants. Therefore, we were interested to see if these changes also correlated to changes in memory performance in each condition.

Recognition memory was measured by d'. This enabled us to control for response bias within the target and foil items. Figure 5 shows the summary of the d' measure for the three conditions over the two testing sessions.

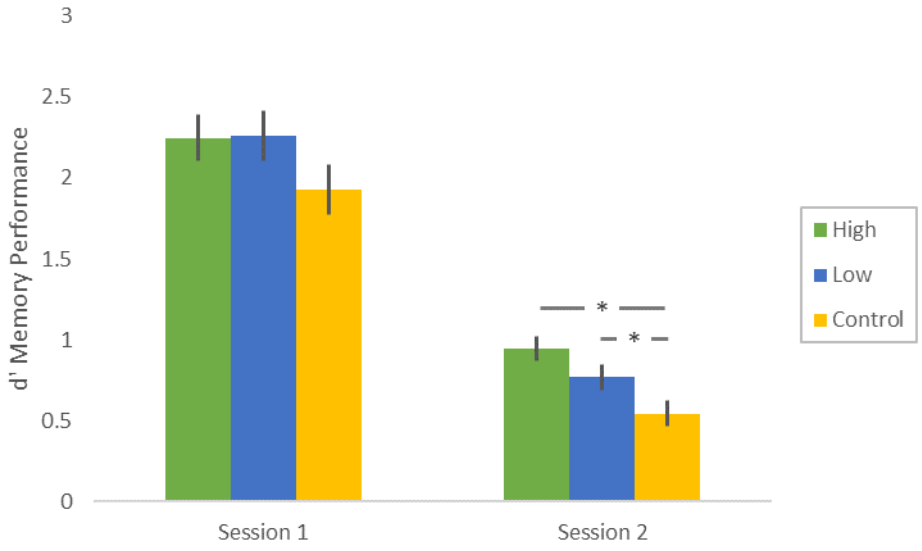


Figure 5. d' memory performance of the participants in different groups and sessions. * $p < 0.05$. Error bars represent one SEM.

To explore the results, Independent sample t-tests were run and showed significant difference between high and control, and marginal significant difference between low and control (see Table 1).

Table 1

Comparison between d' memory performance of different conditions for the two sessions using two independent-sample t-tests.

Comparison	**Session 1**	**Session 2**
High vs Low	t (66) = -.06, p = .952	t (66) = 1.53, p = .130
High vs Control	t (67) = 1.51, p = .017	t (67) = 3.58, p = .001
Low vs Control	t (61) = 1.55, p = .128	t (61) = 2.35, p = .022

To investigate the significance of the above pattern of results within the three conditions of High, Low and Control we conducted a mixed factor ANOVA. We found a significant main effect of condition and a significant main effect of session (see table 2)

Table 2

Summary of mixed-factor ANOVA with Condition (High/Low/Control) as between subject factor and Session as within factor on memory performance d'.

Effect	**F**	**p**	η_p^2
Main effect of Condition	F (2, 97) = 3.14	.048	0.061
Main effect of Session	F (1, 97) = 508.07	< .001	0.840
Interaction effect of Condition × Session	F (2, 97) = .804	.451	.016

As main effect of Condition was significant, we ran post hoc independent-sample t-tests to compare d' between different conditions. Table 3 summarises these comparisons.

Table 3

Summary of post hoc independent sample t-tests on different Conditions (High/Low/Control) on memory performance d'.

Effect	**t**	**p**	**Cohen's d**
High vs. Low	t(66) = 0.762	0.449	0.188
High vs. Control	t(67) = 2.763	0.007*	0.675
Low vs. Control	t(61) = 2.107	0.039	0.54

Note: * $p < 0.05$

To investigate the rate of forgetting in the two groups of High and Low, we ran a 2 × 2 mixed-factor ANOVA on d' values with Session and Condition as independent factors (see table 4). We found no significant main effect of condition, but we did find a significant main effect of session, thereby supporting that timing between arousal and test is important.

Table 4

Summary of mixed-factor ANOVA with Condition (High/Low) as between subject factor and Session as within factor on memory performance d'.

Effect	**F**	**p**	η_p^2
Main effect of Condition	F (1, 66) = .289	.592	.004
Main effect of Session	F (1, 66) = 346.28	< .001	.840
Interaction effect of Condition × Session	F (1, 66) = 1.596	.211	.024

To further explore this data a summary of correct recognition and false recognition for the three conditions across both sessions was run (see table 5). *The results of the false alarm rate suggest that the high condition facilitated less forgetting over time.*

Table 5

Summary of the Hit and False Alarm rates (mean [SD]) for different groups across the two sessions.

	Hit Rate		False Alarm	
Group	Session 1	Session 2	Session 1	Session 2
High	0.75[0.15]	0.66[0.14]	0.10[0.07]	0.33[0.14]
Low	0.76[0.12]	0.65[0.13]	0.10[0.07]	0.37[0.15]
Control	0.74[0.14]	0.61[0.13]	0.14[0.09]	0.41[0.10]

As participants were asked to respond to whether they recognised the stimulus as quickly as possible we investigated response times across conditions and sessions. Please see table 6. The rests suggest that response time was longer over all conditions in the second session compared to the first session.

Table 6

Summary of the response times (seconds, mean [SD]) for the two sessions across conditions.

Condition	**Session 1**	**Session 2**
High	1.24[0.78]	1.50[1.18]
Low	1.28[1.27]	1.46[1.25]
Control	1.32[0.95]	1.49[1.19]

To investigate whether these results were influenced by individual differences, we ran a mixed-factor ANCOVA to investigate personality as covariate. Table 7 summarises the results of this. There were significant effects for condition and for session, suggesting that personality may affect performance in the three conditions and within sessions. Within the HEXACO scale we

found a significant main effect of extraversion suggesting that extraversion plays an important role in the observed effects and interaction effect of extraversion and session. A significant main effect of emotionality was found, but no significant interaction effect of emotionality and session. All other personality effects were insignificant.

Table 7

Summary of the mixed-factor ANCOVA with Condition and Session as between and within subject factors and Personality as covariate on memory performance d'

Personality trait	**Effect**	**F**	***p***	η_p^2
	Main effect Session	F (1,91) = 4.924	.029	.051
	Main effect Condition	F (2,91) = 3.724	.028	.076
	Interaction effect Session × Condition	F (1,91) = 4.981	.028	.052
Extraversion	Main effect Extraversion	F (1,91) = 4.671	.033	.049
	Interaction effect Extraversion × Session	F (1,91) = 4.981	.028	.052
Emotionality	Main effect Emotionality	F (1,91) = 3.952	.050	.042
	Interaction effect Emotionality × Session	F (1,91) = .411	.523	.004
Agreeableness	Main effect Agreeableness	F (1,91) = .675	.414	.007
	Interaction effect Agreeableness × session	F (1,91) = .104	.747	.001
Honesty Humility	Main effect honesty humility	F (1,91) = .102	.750	.001
	Interaction effect Honesty humility × session	F (1,91) = .466	.496	.005
Openness to experience	Main effect openness	F (1,91) = .067	.796	.001
	Interaction effect Openness × session	F (1,91) = .094	.760	.001
Conscientiousness	Main effect conscientiousness	F (1,91) = .037	.847	.001
	Interaction effect conscientiousness × session	F (1,91) = .494	.484	.005

To investigate the above significant results of extraversion, a median split was used to split the data into two groups of introverts (scores <= 3.2) and extraverts (scores > 3.2). A mixed-factor ANOVA with Condition and Extraversion as between subject factors and Session as the within subject factor on memory performance was run. We found as significant main effect of session and condition, and a marginally significant interaction between extraversion and session, suggesting that

those with the personality trait of extraversion may forget less over time. Table 8 summarises the results of this analysis.

Table 8

Summary of the mixed-factor ANOVA with Session as within subject factor and Condition and Extraversion (Introvert/Extravert) as between subject factors.

Effect	**F**	**p**	η_p^2
Main effect of Session	F (1, 94) = 470.342	< 0.001*	0.833
Main effect of Condition	F (2, 94) = 3.204	.045*	0.064
Main effect of Extraversion	F (1, 94) = 2.315	.131	0.024
Interaction Session × Condition	F (2, 94) = 1.164	.317	0.024
Interaction Session × Extraversion	F (1, 94) = 3.642	.059†	0.037
Interaction Condition × Extraversion	F (2, 94) = 1.246	.292	0.026
3-way Interaction	F (2, 94) = 2.069	.132	0.042

Notes: * $p < 0.05$, † marginally significant

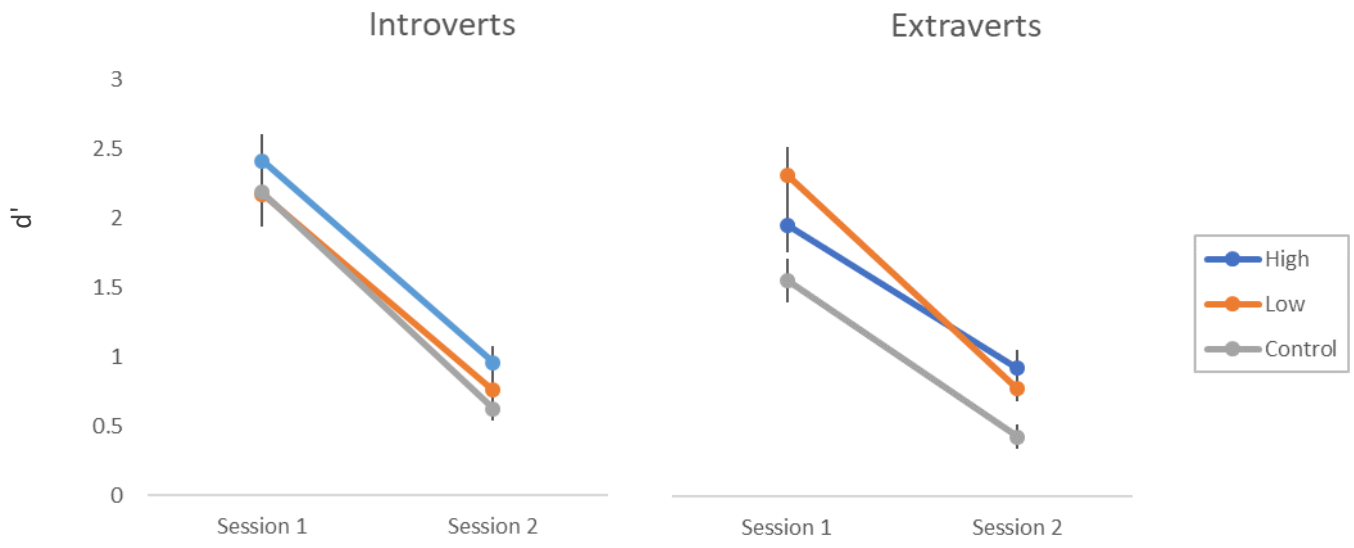
To explore the results further, we ran separate mixed-factor ANOVA's for Introverts and Extraverts with Condition as between subject factor and Session as within subject factor. We found that both introverts and extraverts had a significant main effect of session. Table 9 shows the summary of this analysis (see also figure 6). Figure 6 shows a trend that introverts remember more in the high condition than in the low or control conditions, however the rate of forgetting over conditions is similar. However, extroverts remember more in the first session in the low condition, but over time remember more when exposed to the high condition. Therefore, the rate of forgetting is greater with extraverts in the low condition than in the high condition. Suggesting that extraverts would benefit from the high arousal condition.

Table 9

Mixed-factor ANOVA with Condition and Session as between and within subject factors over memory performance d' split based on Extraversion (Introverts/Extraverts)

Extraversion	**Effect**	**F**	**p**	η_p^2
Introverts	Main effect of Session	F (1, 51) = 256.816	< 0.001*	0.834
	Main effect of Condition	F (2, 51) = 1.062	.353	0.040
	Interaction Session × Condition	F (2, 51) = 0.221	.802	0.009
Extraverts	Main effect of Session	F (1, 43) = 223.353	< 0.001*	0.839
	Main effect of Condition	F (2, 43) = 4.139	.023*	0.161
	Interaction Session × Condition	F (2, 43) = 4.040	.025*	0.158

Note: * p < 0.05



(a) (b)

Figure 6. Main and interaction effects of introverts and extraverts. Error bars refer to one SEM.

To investigate whether different conditions of High, Low and Control are significantly different in the Extravert group, we ran post hoc comparisons. These comparisons showed a significant difference between High and Control (p = .046), a significant difference between Low and Control (p = .007), and a non-significant difference between High and Low (p = .589) conditions.

The interaction effect between Condition and Session was also significant. Therefore, post hoc independent-sample t-tests were run to compare performance of different groups in different sessions. Table 10 shows the summary of these comparisons.

Table 10

Summary of the post hoc independent-sample t-tests investigating the interaction of Condition and Session for extraverts

Session	**Effect**	**t**	**p**	**Cohen's d**
1	High vs. Low	t(31) = 1.209	0.236	0.434
	High vs. Control	t(24) = 1.555	0.133	0.635
	Low vs. Control	t(31) = 2.717	0.011*	0.976
2	High vs. Low	t(31) = 0.923	0.363	0.332
	High vs. Control	t(24) = 3.088	0.005*	1.261
	Low vs. Control	t(31) = 2.573	0.015*	0.924

Note: * $p < 0.05$

We also ran an ANCOVA with session as within subject factor, condition as between subject factor and menstrual phase at the time of the first testing session as covariate. Table 11 summarises the results of this test. This test showed no significant effects suggesting that menstrual cycle did not effect forgetting.

Table 11

Summary of the ANCOVA with Menstrual Cycle as the covariate.

Effect	**F**	***p***	η_p^2
Main effect of Menstrual Cycle	F (1, 56) = 1.543	.219	0.027
Main effect of Condition	F (2, 56) = 2.793	.070	0.091
Main effect of Session	F (1, 56) = 0.203	.654	0.004
Interaction effect of Session × Menstrual Cycle	F (1, 56) = 1.757	.190	0.030
Interaction effect of Condition × Session	F (2, 56) = 0.452	.639	0.016

To further explore the data and to ensure that participants were in a comparable day of their menstrual cycle, we ran three independent-sample t-tests between groups with menstrual cycle in

the first session as the dependent variable. Table 12 summarises these tests showing no-significant difference between the groups.

Table 12

Summary of the comparisons of day of menstrual cycle (mean [SD]) between the groups

Comparison	**Group 1**	**Group 2**	**t**	***p***	**Cohen's d**
High vs Low	14.71[7.85]	14.62[8.04]	t(50) = 0.040	.968	0.011
High vs Control	14.71[7.85]	12.43[8.65]	t(57) = 1.062	.293	0.281
Low vs Control	14.62[8.04]	12.43[8.65]	t(47) = 0.903	.371	0.271

To investigate the individual differences of taking hormonal contraceptives, participants were split based on the method of contraceptives (hormonal/non-hormonal) they used. We ran a mixed-factor ANOVA with Condition and Contraceptives as between subject factor and Session as within subject factor. The analysis found no significant main effect of contraceptives, suggesting that hormonal contraceptive use did not influence the results in this study. Table 13 shows the summary of this analysis.

Table 13

Summary of the effects of mixed-factor ANOVA with Condition and Contraceptives as between subject factors and Session as within subject factor on memory performance d'.

Effect	**F**	***p***	η_p^2
Main effect of Condition	F (2, 65) = 3.384	.040	0.094
Main effect of Session	F (1, 65) = 50.684	<0.001	0.438
Main effect of Contraceptives	F (1, 65) = 0.014	.905	0.000
Interaction of Session × Contraceptives	F (1, 56) = 1.757	.190	0.030
Interaction of Session × Condition	F (2, 65) = 0.492	.614	0.015

Discussion

Our experiment explored whether different arousal interventions would manipulate physiological responses of heart rate and SpO2, how differences in arousal levels and time of testing affect memory performance, and whether these were related to individual differences of personality, menstrual cycle and hormonal contraceptive use. We found that High arousal induced significantly different SpO2 but no significant difference in heart rate, however, conversely, low arousal induced significant change in heart rate, but no significant change in SpO2. Further, high arousal was found to be significantly more beneficial to memory than control over both sessions, and low arousal was more beneficial for memory consolidation compared to control on the second session (Table 1), supporting that the arousal level following encoding and test time is important. As this effect was stronger on the later test, this highlights the importance of retention interval on consolidation. Analyses on personality found a significant main effect of extraversion and also of emotionality. This was interesting as extraversion has been linked to arousal. We found no significant effects for menstrual cycle or hormonal contraceptive use.

Our findings support the Easterbrook (1959) hypothesis that high arousal can enable enhanced recall, even for neutral stimuli when compared to control. Importantly our results add to existing literature by suggesting that consolidation of neutral stimuli can be enhanced by both high and low arousal when compared to control, but also that timing of test is important. Our results found that there was no difference in memory performance of those in the low condition compared to those in the high condition when tested 30 minutes after intervention ($p=.952$). There was also no difference in memory performance found between the two groups in the second session one week later ($p=.130$). Those in the high condition had significantly better memory performance compared to control both 30 minutes after encoding ($p=.017$), and 1 week later ($p=.001$). Those in the low condition exhibited significantly better memory performance than those in the control condition when tested one week after intervention ($p=.022$). Thereby supporting that high and low arousal can

enhance memory of neutral stimuli and that high arousal as opposed to low arousal affects memory more positively over time.

Further, our findings in the high condition, which show slower forgetting when tested one week later ($p = 0.001$ compared to Control and $p = 0.130$ compared to low), may support Sharot and Phelps (2004) who found that heightened arousal was related to a slower rate of forgetting over time. A slower rate of forgetting over time is also supported by studies showing increased neurotransmitter activity during times of high arousal (Mather et al., 2016). Mather et al. (2016) theorised that norepinephrine projected from the Locus Coeruleus when activated by glutamate release following arousal, enables enhanced consolidation by creating memory hotspots. One possible explanation for our results where those in the high condition forgot less over time is that consolidation had been enhanced through neurotransmitter release following the arousal of pain. A further explanation for the high arousal condition showing less forgetting over time may come from Weymar, Schwabe, Low, and Hamm, (2012) who found during EEG study that that physiological arousal evokes late positive potentials, thereby enabling enhanced recognition recall. However, interestingly, our results do not support Schwabe (2016) who found that glucocorticoid secretion which is triggered by high arousal enhanced memory 15-20 minutes after onset, as we found the results of high arousal when compared to control to be more significant after a longer retention time of one week ($p=.017$ session 1, and $p=.001$ session 2, Table 1).

When analysing the effect of personality and condition, our results do not support previous research or our hypotheses that the high arousal condition would enhance memory performance of extraverts. Based on empirical evidence (Eysenck, 1976), we would have expected extraverts to have better memory in the high condition. This is based on findings that extraverts have a lower level of arousal, and therefore heightening arousal may provide a more optimum level to enhance memory. We found no difference in memory performance for extraverts in the high condition compared to the low condition on the first test, or on the second test one week later.

Further, based on empirical suggestions that introverts have a higher baseline arousal level (Eysenck, 1976), we hypothesized that the low arousal condition would have been beneficial for consolidation as it would have lowered the arousal level of these participants to an optimum level for memory. However, we did not find any difference in memory performance for introverts in the high arousal condition compared to the low arousal condition at either times of testing. Interestingly the rate of forgetting in both conditions for introverts was similar. These findings do not support previous research. Our findings suggest that as mindfulness is thought to enhance memory with practice, our intervention was not of a long enough duration to lower arousal for introverts to be beneficial for memory consolidation. However, as we were able to obtain a partial hypothesis for extraverts, our results do suggest that there may be some long-term advantage for memory consolidation of neutral information over time for extraverts when arousal precedes consolidation.

Our physiological measurements garnered some compelling results, with SpO2 and pulse rate showing differing results depending on high or low condition. Interestingly, our results showed significantly higher SpO2 in the high condition, suggesting that blood oxygenation levels raised during the ice bucket intervention. However, pulse rate stayed steady during this time. We believe that this is the first study to investigate SpO2 levels at a behavioural level.

In the low condition we found an inverse effect of SpO2 and pulse rate, with a significant difference of pulse, but no difference in SpO2. This significant difference in pulse rate at around 50 – 80 seconds of intervention may suggest that participants were more relaxed at the start of the mindfulness intervention. However, we did not measure pulse of participants in the control condition, therefore consideration must be made that this difference in pulse rate may be due to sitting still rather than the mindfulness intervention.

We found that menstrual phase or hormonal contraceptive use did not affect consolidation in this study. This does not support some previous literature that suggest these may affect memory (Kuhlmann & Wolf, 2005). However, previous studies have not used the same methodology as this

study and have not directly compared how differing arousal levels affect consolidation of the same stimuli. Further, although previous studies associated menstrual phase with memory performance, these studies have measured cortisol level and correlated this with memory performance. This study did not measure cortisol levels, and only found no significant differences on a behavioural level. Thereby suggesting that cortisol levels may be associated with memory, but menstrual phase may not.

There were several limitations to our study that should be considered. We did not include an intervention for the control group. Therefore, if we had measured SpO2 and pulse rate for control group during an intervention we would have been able to ascertain whether the significant effect of pulse rate in the low condition was due to the mindfulness intervention. Further, mindfulness practice may have been too brief, as empirical evidence shows that a more practised mindfulness practitioner is able to exhibit enhanced attention and memory skills compared to novice practitioners. Although this research included a question on how well participants were able to concentrate on the mindfulness intervention, it did not include a question as to whether they practise mindfulness regularly. It would be beneficial to measure this, so that we could gauge how participants may have reacted to the intervention, as those who practise regularly may have been more efficient at lowering arousal levels than those who do not practise regularly.

Additionally, our methodology of measuring physiological response is different to many studies that measure cortisol levels and correlate these with memory performance. As our study measured SpO2 and pulse rate, these cannot be directly compared with other studies.

This study exceeds previous literature as it compares high and low arousal within one study using the same neutral stimuli for both conditions, thereby enabling a more detailed investigation into how arousal affects consolidation. This study also utilises physiological methodology of SpO2 and pulse rate to investigate how these correlates with memory performance and how arousal may affect performance of different personality types.

Future directions could investigate whether longer or repeated interventions would be beneficial to consolidation of neutral information. However, care would be needed especially in the high arousal conditions that participants did not get habituated to the iced water. Because we found only marginal significance in the low condition, this study could be repeated with more experienced mindfulness practitioners, or with an enhanced mindfulness intervention with practice over time. This may garner different results and make a clearer distinction as to whether mindfulness does enhance consolidation of neutral information. Further, future studies could investigate the brain correlations of consolidation in both the high and low conditions, to make clearer distinctions into how the two conditions may aid consolidation of the neutral information. Additionally, as many previous studies have correlated cortisol levels with memory, and this study looked to see if there was a relationship between SpO2 and pulse and memory, future directions could include investigations into whether there is a relationship between cortisol levels and SpO2 and pulse as this may lead to further investigations into how physiological reactions to arousal may impact memory. Finally, the study should be replicated to include males to see if the effects replicate over genders.

Overall this research adds to the literature of how arousal affects consolidation by suggesting that neutral stimuli may be enhanced through both high and low arousal, although timing of test is important. It suggests that high arousal is more beneficial for memory over time generally, although it does suggest that more research would be beneficial to investigate the amount of mindfulness required for optimum memory performance. Moreover, future directions should help to investigate this area in more depth and uncover more of the contradictory results found in the current literature. This could have wide ranging implications in everyday life and for those in education who are often required to consolidate information of neutral content.

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Appendix A

Hexaco Personality Questionnaire

HEXACO-PI-R

(SELF REPORT FORM)

DIRECTIONS

On the following pages you will find a series of statements about you. Please read each statement and decide how much you agree or disagree with that statement. Then write your response in the space next to the statement using the following scale:

5 = strongly agree
4 = agree
3 = neutral (neither agree nor disagree)
2 = disagree
1 = strongly disagree

Please answer every statement, even if you are not completely sure of your response.

Please provide the following information about yourself.

Sex (circle): Female Male

Age: _____ years

1 I would be quite bored by a visit to an art gallery.
2 I plan ahead and organize things, to avoid scrambling at the last minute.
3 I rarely hold a grudge, even against people who have badly wronged me.
4 I feel reasonably satisfied with myself overall.
5 I would feel afraid if I had to travel in bad weather conditions.
6 I wouldn't use flattery to get a raise or promotion at work, even if I thought it would succeed.
7 I'm interested in learning about the history and politics of other countries.
8 I often push myself very hard when trying to achieve a goal.
9 People sometimes tell me that I am too critical of others.
10 I rarely express my opinions in group meetings.
11 I sometimes can't help worrying about little things.
12 If I knew that I could never get caught, I would be willing to steal a million dollars.
13 I would enjoy creating a work of art, such as a novel, a song, or a painting.
14 When working on something, I don't pay much attention to small details.

15 People sometimes tell me that I'm too stubborn.
16 I prefer jobs that involve active social interaction to those that involve working alone.
17 When I suffer from a painful experience, I need someone to make me feel comfortable.
18 Having a lot of money is not especially important to me.
19 I think that paying attention to radical ideas is a waste of time.
20 I make decisions based on the feeling of the moment rather than on careful thought.
21 People think of me as someone who has a quick temper.
22 On most days, I feel cheerful and optimistic.
23 I feel like crying when I see other people crying.
24 I think that I am entitled to more respect than the average person is.
25 If I had the opportunity, I would like to attend a classical music concert.
26 When working, I sometimes have difficulties due to being disorganized.
27 My attitude toward people who have treated me badly is “forgive and forget”.
28 I feel that I am an unpopular person.
29 When it comes to physical danger, I am very fearful.
30 If I want something from someone, I will laugh at that person's worst jokes.

Continued…

31 I've never really enjoyed looking through an encyclopedia.
32 I do only the minimum amount of work needed to get by.
33 I tend to be lenient in judging other people.
34 In social situations, I'm usually the one who makes the first move.
35 I worry a lot less than most people do.
36 I would never accept a bribe, even if it were very large.
37 People have often told me that I have a good imagination.
38 I always try to be accurate in my work, even at the expense of time.
39 I am usually quite flexible in my opinions when people disagree with me.
40 The first thing that I always do in a new place is to make friends.
41 I can handle difficult situations without needing emotional support from anyone else.
42 I would get a lot of pleasure from owning expensive luxury goods.
43 I like people who have unconventional views.
44 I make a lot of mistakes because I don't think before I act.
45 Most people tend to get angry more quickly than I do.
46 Most people are more upbeat and dynamic than I generally am.
47 I feel strong emotions when someone close to me is going away for a long time.
48 I want people to know that I am an important person of high status.
49 I don't think of myself as the artistic or creative type.
50 People often call me a perfectionist.
51 Even when people make a lot of mistakes, I rarely say anything negative.
52 I sometimes feel that I am a worthless person.
53 Even in an emergency I wouldn't feel like panicking.
54 I wouldn't pretend to like someone just to get that person to do favors for me.
55 I find it boring to discuss philosophy.
56 I prefer to do whatever comes to mind, rather than stick to a plan.
57 When people tell me that I'm wrong, my first reaction is to argue with them.
58 When I'm in a group of people, I'm often the one who speaks on behalf of the group.
59 I remain unemotional even in situations where most people get very sentimental.
60 I'd be tempted to use counterfeit money, if I were sure I could get away with it.

Appendix B

Menstrual and Contraceptive Questionnaire

1. Profession (If student, your field of study)
2. How many hours do you usually sleep at night?
3. Do you feel like that amount of sleep is enough for you?
4. If no or other to above question, please explain.
5. When do you usually go to bed at night-time?
6. When do you usually wake up in the morning time?
7. How many hours did you sleep on the night before the first session?
8. How was your sleep? Did you sleep well?
9. Please specify the types of drink you drank within the 12 hours before the first session
10. Do you usually take any drugs/medications?
11. If yes or other to the above question, please explain
12. Did you take any drugs within the 12 hours before the first session?
13. If yes or other to the above question, please explain.
14. Have you had any brain stimulation during the past 48 hours?
15. Do you smoke?
16. Did you smoke within 12 hours before the first session?
17. If yes to the above question, please specify how many.
18. How long is your menstrual cycle? Please enter one number if your cycle is regular or a range if your cycle is irregular.
19. What date did you start your last period? (Day, Month, Year).
20. Since last period?
21. Do you use contraception?
22. What type of contraception do you use?
23. Please enter the name of the product you use.

Appendix C

Participant Consent form

University of Kent | School of Psychology

CONFIDENTIAL

Participant Consent Form

Circle as Applicable

1. Have you read the information sheet about this study? YES/NO
2. Have you had an opportunity to ask questions and discuss this study? YES/NO
3. Have you received satisfactory answers to all your questions? YES/NO
4. Have you received enough information about this study? YES/NO
5. To whom have you spoken about this study? Amir-Homayoun Javadi / _____
6. Do you understand that you are free to withdraw from this study
   *At any time YES/NO
   *Without giving a reason for withdrawing YES/NO
7. Do you agree to take part in this study? YES/NO

I consent to the processing of my personal information for the purposes of this study only and that it will not be used for any other purpose. I understand that such information will be treated as strictly confidential and handled in accordance with the provisions of the Data Protection Act 1998.

Signed _____ Date _____

Name of volunteer _____

Name of Investigator: Amir-Homayoun Javadi Signature of Investigator:

Appendix D

Participant Information Sheet High Arousal Condition

University of Kent | School of Psychology

Participant Information Sheet

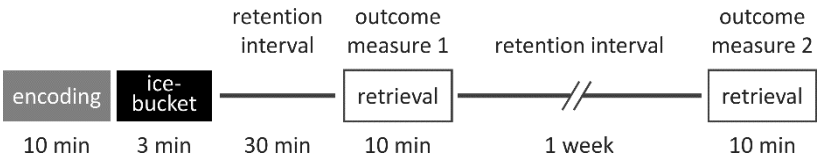
You are being invited to take part in a research study. Before you decide, it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully. Please ask if anything is unclear, and do not feel rushed into making a decision.

Study Aim

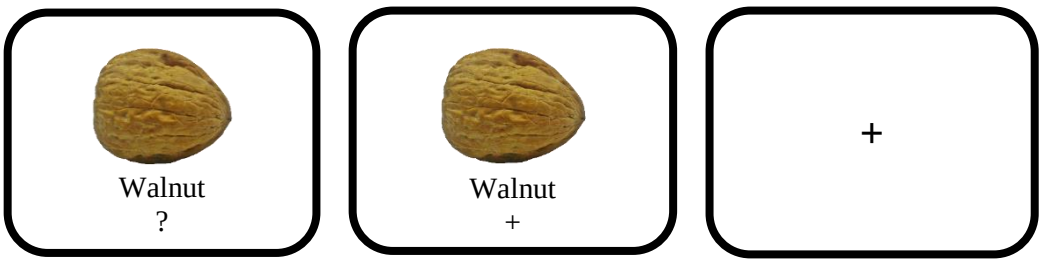
The aim of the study is to investigate whether stress can change memory performance in a long-term memory task, and whether this is moderated by personality, contraceptive use and menstrual cycle.

What will happen to me in the study?

Each participant will take part in two sessions. The first session will take approximately 60 minutes, and the second session, one week later will take approximately 15 minutes. You will receive 5 RPS credits after completion of the study. You will be asked to complete a contraceptives and menstrual phase questionnaire. We need to collect menstrual phase and contraceptive data as these have been shown to affect stress which are important to the analysis of our study. A heart rate monitor will be clipped to your finger and you will be asked to complete a memorisation task followed by immersing your other hand in a bucket of iced water for 3 minutes. You will then be asked to spend 30 minutes completing an online jigsaw puzzle followed by a recognition task.



During the memorisation task you are asked to memorise two blocks of 40 objects presented with corresponding words. The objects will be presented as follows: an image of the object on top and the word on the bottom. **You need to try to memorise the object.** Please try to memorise the concept of the objects to the best you can.



You will then have a 3 minute intervention of hand immersed in bucket of iced water, followed by 30 minutes completing an online jigsaw, and an old new recognition test for the words that you memorised in the memorisation phase. You will be asked to press left arrow key if the word is 'old' – it is from the list of words you

remembered, or the right arrow key if the word is new, and not from the list of words you remembered. Hold your index and middle fingers on the two keys and respond as accurately as possible. If in doubt, try to make the best choice. You will need to return to the lab one week later to complete only the recognition task and a personality questionnaire.

What will happen if I don't want to carry on with the study?

You are free to withdraw from the study at any time, and you will not suffer any penalty or loss of rights. If you do choose to withdraw or are no longer able to participate, then unless verbally directed otherwise the study investigators will keep the data collected up to that point. You should be also aware that your participation can be withdrawn by the study investigators.

Are there any negative side-effects?

We do not anticipate any significant side-effects although some participants may feel a little tired after the test session.

What will happen to the results of the research study?

The results of this study will be used to better understand the brain processes that support human learning and memory. The results of the present study may be published for scientific purposes, but your records or identity will not be revealed unless required by law.

What happens to the information I provide?

Participation in this study guarantees confidentiality of the information you provide. No one apart from the researcher and research supervisor will have any access to the information you provide. Your name and any other identifying information will be stored separately from your data in a securely locked filing cabinet. Questionnaires will be stored in a securely locked room for as long as is required by the Data Protection Act, and then they will be destroyed by our confidential shredding service.

Who has reviewed this study?

The study has been approved by the School of Psychology, University of Kent Research Ethics committee.

What if there is a problem?

If you have a concern about any aspect of the study then you should speak with Dr Amir-Homayoun Javadi, who is director of the study. He can be reached on 01227 82 7770. If you remain unhappy and wish to complain formally, you can do this through the School of Psychology Chair of Ethics. Further details can be obtained from the School of Psychology General Office on 01227 824775.

Who is organising the research?

The research is organised by Dr Amir-Homayoun Javadi, School of Psychology, University of Kent

Email: a.h.javadi@kent.ac.uk, Phone: 01227 82 7770

Appendix E

Participant Information Sheet Low Arousal Condition

University of Kent | School of Psychology

Participant Information Sheet

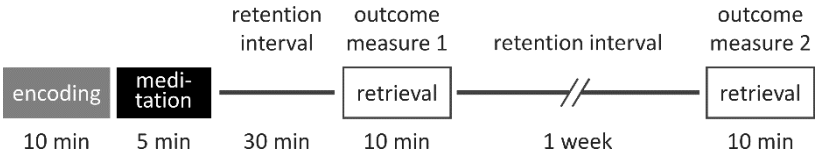
You are being invited to take part in a research study. Before you decide, it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully. Please ask if anything is unclear, and do not feel rushed into making a decision.

Study Aim

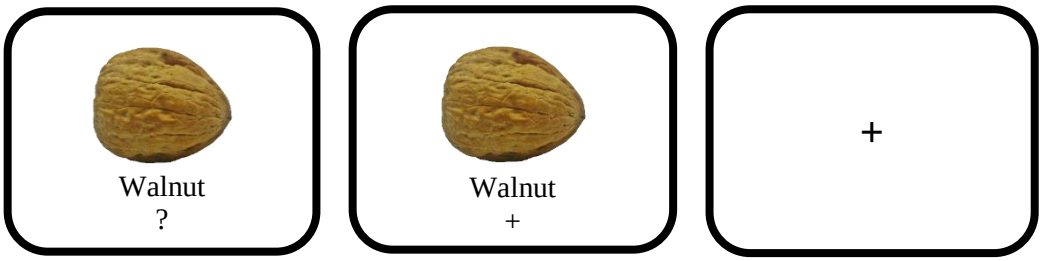
The aim of the study is to investigate whether stress can change memory performance in a long-term memory task, and whether this is moderated by personality, contraceptive use and menstrual cycle.

What will happen to me in the study?

Each participant will take part in two sessions. The first session will take approximately 60 minutes, and the second session, one week later will take approximately 15 minutes. You will receive 5 RPS credits after completion of the study. You will be asked to complete a contraceptives and menstrual phase questionnaire. We need to collect menstrual phase and contraceptive data as these have been shown to affect stress which are important to the analysis of our study. A heart rate monitor will be clipped to your finger and you will be asked to complete a memorisation task followed by guided meditation for 5 minutes. You will then be asked to spend 30 minutes completing an online jigsaw puzzle followed by a recognition task.



During the memorisation task you are asked to memorise two blocks of 40 objects presented with corresponding words. The objects will be presented as follows: an image of the object on top and the word on the bottom. **You need to try to memorise the object.** Please try to memorise the concept of the objects to the best you can.



You will then have a 5 minute intervention of guided meditation, followed by 30 minutes completing an online jigsaw, and an old new recognition test for the words that you memorised in the memorisation phase. You will be asked to press left arrow key key if the word is 'old' – it is from the list of words you remembered, or the right arrow key if the word is new, and not from the list of words you remembered. Hold your index and middle fingers on the two keys and respond as accurately as possible. If in doubt, try to make the best choice. You will need to return to the lab one week later to complete only the recognition task and a personality questionnaire.

What will happen if I don't want to carry on with the study?

You are free to withdraw from the study at any time, and you will not suffer any penalty or loss of rights. If you do choose to withdraw or are no longer able to participate, then unless verbally directed otherwise the study investigators will keep the data collected up to that point. You should be also aware that your participation can be withdrawn by the study investigators.

Are there any negative side-effects?

We do not anticipate any significant side-effects although some participants may feel a little tired after the test session.

What will happen to the results of the research study?

The results of this study will be used to better understand the brain processes that support human learning and memory. The results of the present study may be published for scientific purposes, but your records or identity will not be revealed unless required by law.

What happens to the information I provide?

Participation in this study guarantees confidentiality of the information you provide. No one apart from the researcher and research supervisor will have any access to the information you provide. Your name and any other identifying information will be stored separately from your data in a securely locked filing cabinet. Questionnaires will be stored in a securely locked room for as long as is required by the Data Protection Act, and then they will be destroyed by our confidential shredding service.

Who has reviewed this study?

The study has been approved by the School of Psychology, University of Kent Research Ethics committee.

What if there is a problem?

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Who is organising the research?

The research is organised by Dr Amir-Homayoun Javadi, School of Psychology, University of Kent

Email: a.h.javadi@kent.ac.uk, Phone: 01227 82 7770

Appendix F

Participant Information Sheet, Control condition

University of Kent | School of Psychology

Participant Information Sheet

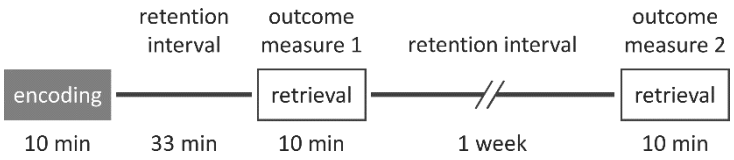
You are being invited to take part in a research study. Before you decide, it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully. Please ask if anything is unclear, and do not feel rushed into making a decision.

Study Aim

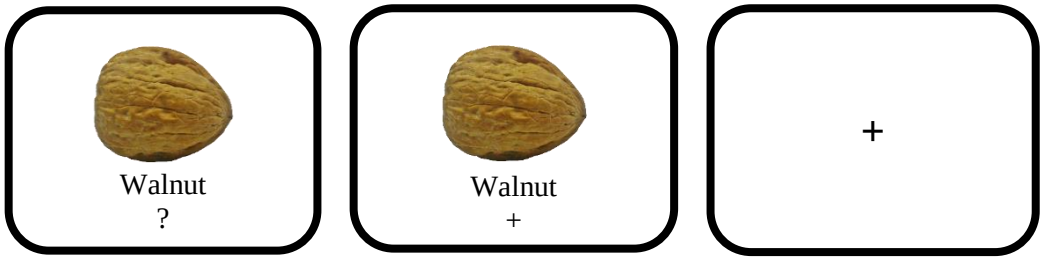
The aim of the study is to investigate whether stress can change memory performance in a long-term memory task, and whether this is moderated by personality, contraceptive use and menstrual cycle.

What will happen to me in the study?

Each participant will take part in two sessions. The first session will take approximately 60 minutes, and the second session, one week later will take approximately 15 minutes. You will receive 5 RPS credits after completion of the study. You will be asked to complete a contraceptives and menstrual phase questionnaire. We need to collect menstrual phase and contraceptive data as these have been shown to affect stress which are important to the analysis of our study. A heart rate monitor will be clipped to your finger and you will be asked to complete a memorisation task followed by 30 minutes completing an online jigsaw puzzle followed by a recognition task.



During the memorisation task you are asked to memorise two blocks of 40 objects presented with corresponding words. The objects will be presented as follows: an image of the object on top and the word on the bottom. **You need to try to memorise the object.** Please try to memorise the concept of the objects to the best you can.



You will then be asked to spend 30 minutes completing an online jigsaw, followed by an old/ new recognition test for the words that you memorised in the memorisation phase. You will be asked to press left arrow key key if the

word is 'old' – it is from the list of words you remembered, or the right arrow key if the word is new, and not from the list of words you remembered. Hold your index and middle fingers on the two keys and respond as accurately as possible. If in doubt, try to make the best choice. You will need to return to the lab one week later to complete only the recognition task and a personality questionnaire.

What will happen if I don't want to carry on with the study?

You are free to withdraw from the study at any time, and you will not suffer any penalty or loss of rights. If you do choose to withdraw or are no longer able to participate, then unless verbally directed otherwise the study investigators will keep the data collected up to that point. You should be also aware that your participation can be withdrawn by the study investigators.

Are there any negative side-effects?

We do not anticipate any significant side-effects although some participants may feel a little tired after the test session.

What will happen to the results of the research study?

The results of this study will be used to better understand the brain processes that support human learning and memory. The results of the present study may be published for scientific purposes, but your records or identity will not be revealed unless required by law.

What happens to the information I provide?

Participation in this study guarantees confidentiality of the information you provide. No one apart from the researcher and research supervisor will have any access to the information you provide. Your name and any other identifying information will be stored separately from your data in a securely locked filing cabinet. Questionnaires will be stored in a securely locked room for as long as is required by the Data Protection Act, and then they will be destroyed by our confidential shredding service.

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Who is organising the research?

The research is organised by Dr Amir-Homayoun Javadi, School of Psychology, University of Kent

Email: a.h.javadi@kent.ac.uk, Phone: 01227 82 7770

Appendix G

Debrief sheet

Debrief

Thank you very much for your participation in this research. We would like to provide some further information about the purpose of the study and what we expect to find.

Studies have shown that high or low amounts of stress can affect memory, and further that this is moderated by personality and in females, by contraceptive use and menstrual cycle phase. To further this research, in this study we want to compare memory performance while participants, are subject to either high or low stress and analyse this with regards to personality. Females in the first half of their menstrual cycle was part of the inclusion criteria because females in the second half of their menstrual cycle have been found to have heightened stress levels, and therefore cortisol levels. As stress and cortisol levels are linked to memory processes, and naturally heighted levels may confound our results, we only analyse data from women in the first half of their cycle when their stress levels are at a base line. We expect to see impaired memory performance in the high stress condition, especially in introverts as stress would heighten their arousal above optimum levels, and we expect to see improved memory performance in extroverts in the high stress group.

If you have any concerns about this research, would like to ask any further questions, please contact the researcher or research supervisor using the contact details below or student support at psychstudentsupport@kent.ac.uk. Alternatively, we can help you to get in touch with available professional services. All conversations will be kept strictly confidential. If you would like to withdraw your data at any point, please contact the Psychology departmental office on 01227 82 3961. If you have been given a participant code you need to cite this. You do not have to give a reason for your withdrawal.

Once again, we would like to thank you for your valuable contribution to this research. Your participation is greatly appreciated.

Yours sincerely,

Susan Absolon – sda22@kent.ac.uk
Selina Muller – som20@kent.ac.uk

Dr Amir-Homayoun Javadi (supervisor)
School of Psychology, University of Kent
E: a.h.javadi@kent.ac.uk T:01227 82 777

If you have any serious concerns about the ethical conduct of this study, please inform the Chair of the Psychology Research Ethics Panel (via the Psychology Department Office) in writing, providing a detailed account of your concern.