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The effects of inciting positive and neutral emotion on working memory performance; the influence of emotion on younger and mid-aged adults.

This study investigated the impact of positive incidental emotion on working memory performance and whether the impact differed for younger (18-33) or slightly older age groups (34-50). Research indicates cognitive decline begins from early adulthood which has an impact on working memory capabilities. There are studies that suggest that positive emotion can improve working memory, but the findings are not conclusive. Moreover, much of the research has focused on either very young adults or much older. In an online experiment, participants with a mean age of 37 were exposed to either neutral or positive images before completing a working memory operational SPAN test. The number of errors made in remembering the presented letters were recorded and then analysed using a 2x2 independent factorial ANOVA. It showed that there was no significant difference in performance between the two age groups. However, it revealed that those participants who were exposed to the positive stimuli performed significantly better than those who encountered the neutral images. The findings suggest that there was no age difference in the ability to complete working memory tests. However, there was a significant indication that positive emotion improved working memory regardless of age but this improvement was not greater for the older age group. Thus, this study found that there was no interaction between age and positive effect.

Introduction

Within the workplace and in all aspects of everyday life, working memory is an essential ability for a range of cognitive skills such as learning, problem-solving and creativity. With the expectation that people will be required to work to an older age, it is important to understand how working memory changes. To deal with numerous types of information from a range of sources, working memory is a complex multi-component system, with two temporary storage systems, an episodic buffer to bind information together and an overriding central control (Kaye, 2022, Baddeley, 2000). However, these cognitive functions begin to decline in performance from early

adulthood throughout middle-age and then into old age. It has been proposed that positive emotion can improve working memory and that these improvements are greater for older adults. Even so, conclusions vary and there is little consistency in research methods which makes comparisons difficult. In addition, most studies focus on either very young or much older adults who may have other influencing factors. Therefore, there is a lack of research into the effects of positive emotion on working memory performance for mid-aged participants.

There are a range of cognitive functions needed for working memory however there is overwhelming research that these functions decline with age. Correlation studies involving large numbers of participants identify a pattern of linear cognitive decline starting from early adulthood (Salthouse, 1996; 2010; 2019). Despite this, Salthouse (2019) acknowledged that in other studies there are inconsistent results for the mid-age group which he claimed were due to practice and experimental effects. The correlation studies suggest clear patterns of decline but they do not give any indication for the reasons for this. Concerned with the causes for age related decline, Kropotov et al. (2016) looked at the neurophysiological changes of 454 healthy participants and found evidence for the slowing of processing speeds which was proposed by Salthouse (1996). They also noticed that deteriorated cognitive functions were compensated by other high performing cognitive areas. This gives support for the compensation theory and plasticity of the brain as it ages and adapts to its environment (Reuter-Lorenz and Cappell, 2008). If emotion processing does not decline in the same way as other cognitive functions, emotion may help compensate for any cognitive decline involved in working memory.

There have been numerous studies about the influence of positive emotion on working memory performance. While looking into verbal and spatial aspects of working memory, Storbeck and Maswood (2016) concluded that positive mood enhanced executive control and helped to prevent irrelevant interference. Likewise, Yang, Yang and Isen (2013) also pointed to improved cognitive control for positive stimuli in comparison to neutral. In contrast, there are studies that have found that positive emotion impairs working memory as it reduces storage capacity and hinders the ability to focus attention (Martin and Kerns, 2011). When using an operational SPAN test, working memory was reduced for all emotional words including positive.

The researchers claimed this gave support for the emotional impairment theory in which emotional stimuli requires additional attention and processing and therefore detracts from the working memory task (Garrison and Schmeichel, 2019). There may be a range of confounding factors that account for the different conclusions made in these studies. Individual differences were identified as a factor by Zhang, Zhang and Liu (2017) in how positive stimuli effected working memory capacity. By using brain scans, they identified that positive emotion enhanced working memory for high-capacity participants, but impaired performance for the low-capacity individuals (Zhang, Zhang and Liu, 2017). Despite some similarities, such as the mean age of participants being 19-23 years for these studies, they all used different ways to measure working memory performance and incited emotion in different ways. Furthermore, contradictory results may be due to the differences in the valence and arousal aspects of the emotional stimulus which can then affect cognition in different ways.

The Circumplex model (Russell, 1980) gives a biological explanation to defining emotion as comprising of varying combinations of valence (evaluation of pleasantness) and arousal (amount of activation). These are independent as they each activate different neural systems; valence triggers dopamine whereas arousal stimulates the amygdala (Hou and Cai, 2022). The impact of valence is relevant to the Neuropsychological theory of positive mood which proposes that increased dopamine levels improve cognitive flexibility and control (Ashby, Isen and Turken, 1999). Yang, Yang and Isen (2013) attributed increased dopamine levels for improved cognitive control resulting in better working memory performance. In addition, the arousal aspect also influences cognition, as identified by Osaka et al. (2013) who concluded that positive emotion activated different neural networks which enhanced working memory performance. Nevertheless, as all emotion is made of different levels of valence and arousal, they both interact to create a cognitive effect. But just looking at valence and arousal does not give a full explanation, and it has been proposed that motivational intensity can also have an impact on cognition.

Gable and Harmon-Jones (2010) conducted a literature review into studies of emotion and identified limitations to the Circumplex model and therefore added a

third aspect of motivation. They concluded low motivation broadens cognitive processes, whereas high motivation narrows cognitive processes (Gable and Harmon-Jones, 2010). This motivational perspective may account for Martin and Kerns' (2011) study where they found emotion broadened attention and prevented participants from focusing on the task and therefore reduced working memory performance. Storbeck and Maswood (2016) also acknowledge the impact of motivation in their study and pointed to the motivational Broaden-and-build theory (Fredrickson, 2001) to explain how positive emotion broadened cognitive ability which then allowed for information to be maintained while processing tasks (Storbeck and Maswood, 2016). Even so, it has been recognised how valence, arousal and motivation all interact to impact on cognition (Storbeck and Maswood, 2016; Hou and Cai, 2022). Emotion varies and is complex, made up of varying amounts of valence, arousal and motivation therefore the type of emotion incited can make an impact and the way individuals respond to that emotion will also differ. Moreover, these studies mainly use young participates usually with a mean age of 20 or less and this is before any cognitive decline so the effects of emotion may differ for older adults.

As working memory declines with age and positive emotion has been seen to improve performance, there may be an interaction between the two. There appears to be a positivity bias for older adults which was illustrated in a working memory experiment where participants remembered faces more positively than they really were (Mok *et al.*, 2019). Furthermore, it was found that when using emotional content, there was less age related differences when completing an operational SPAN test (Mammarella *et al.*, 2013). To understand the biological effects of emotional stimuli, brain scans revealed that older participants used two neural pathways, whereas younger adults only used one (Ziaei, Salami and Persson, 2017). This gives some support for the compensation theory and the plasticity of the brain as it ages (Reuter-Lorenz and Cappell, 2008). Although these experiments differed, as the research that looked at the interaction of aging and emotion on working memory performance tended to use integrated emotional stimuli unlike the incidental stimuli used in other studies. The way the emotion is encountered can influence cognitive performance. Dodd et al. (2017) found that task irrelevant emotion, such as incidental emotional stimuli, disrupted cognitive performance, whereas when the

emotional stimuli was integral to the task, it facilitated performance. However, their study looked at participants with a mean age of 20 and their conclusions differed from those who did find a positive effect with incidental stimuli. There appears to be little research into the effects of incidental emotion on working memory performance for older adults.

There is considerable evidence to show that aging results in progressive decline in cognitive control and therefore a reduction in working memory capabilities. It has been suggested that positive emotion can improve working memory performance, although the research is not conclusive and results vary. These studies often have a mean age of around 20 and there are few studies that purposely look at mid-aged adults who, according to linear representations from large correlation studies, may be experiencing the early stages of cognitive decline. By comparing the effects of positive emotion on this group, it may offer some insights into how cognition changes with age and how the biological and motivational aspects of emotion impact performance. There appears to be support for a positivity bias for much older adults but these studies tended to focus on integrated emotional stimuli in contrast to studies with younger participants that often used incidental emotion.

The aim of this study was to identify whether inciting positive emotion before completing a working memory test resulted in higher test scores and whether this differed between younger and mid-aged adults. The findings may lead to a greater understanding of the influence of motivational and biological factors on working memory performance. In this study, a working memory experiment enabled the concept of working memory performance to be operationalized into the number of errors to be measured and compared for different emotional stimuli (positive and neutral) and two different age groups (18-33 and 34-50).

The research question addressed to what extent did prior positive emotion effect working memory and did this differ between younger and mid-aged adults. The first hypothesis proposed that younger adults would make fewer errors in a working memory task for both positive and neutral conditions. The second hypothesis predicted that positive emotion prior to completing a working memory task would lead to fewer errors regardless of age. Finally, the third hypothesis looked at the

interaction between the two conditions and predicted that the difference between the number of errors between the two age groups for the positive emotion would be less than for the neutral condition.

Methodology

Design

To investigate the impact of positive emotion on working memory for different age groups, an experimental, between-participants design was used. The dependant variable of working memory performance was operationalized by measuring the number of errors made on a shortened operational SPAN (Foster *et al.*, 2015). The first independent variable had two conditions of emotion with participants exposed to either positive or neutral stimuli. For the second independent variable, participants were arranged into two age groups (18-33 and 34-50) which was similar to other studies (Kropotov *et al.*, 2016). Data on the number of errors on the memory aspect of the test were statistically analysed using a 2 x 2 independent factorial ANOVA (analysis of variance) to test the null hypothesis and to identify any interaction between emotion and age for working memory performance.

Participants

Opportunity sampling was used to recruit participants online via the Open University Sona website and via informal university Facebook groups to allow for sufficient numbers of participants. It was likely that the majority were university students and they were aged between 18 and 50. No other personal details were collected as they were not relevant to the research aims. As this was a between-groups design, 60 participants were originally recruited but this was extended 70 to ensure a minimum of 10 for each combination of age group and emotion type. At the start of the online experiment, participants were informed of the purpose of the study, details of the activity, the type of data collected (age and number of errors) and the expected timings. They gave informed consent by clicking a box to say that they agreed and freely gave their consent before they could continue with the experiment. The study was approved by the Open University ethics. Consideration was given to data protection and participants were informed that details of consent and data would be

safely stored electronically in separate, password protected folders and would be deleted after the course results had been released.

Participants were informed at the start and end of the experiment that they could withdraw from the study at any point during and up to the point that their data had been fully anonymised (30th April 2024). The debrief reminded participants of the purpose of the study, their right to withdraw and how their data would be treated. Contact details were supplied if they wanted any additional information from the researcher and who they could contact if they wished to make a complaint.

Participants were randomly allocated to each condition (either positive or neutral emotion) so that individual differences were spread across groups. As the emotional stimuli were either neutral or positive, it was unlikely to have created any negative feelings and the maths questions only required basic number knowledge, so should not have caused any distress. Even so, participants were able to exit the experiment at any time (British Psychological Society, 2021).

Materials

The experiment was created using Gorilla software. To begin with, it included information about the experiment and detailed consent. Images were sourced from the Oasis project (Kurdi, Lozano and Banaji, 2017) which had already been rated for their levels of emotional stimulus and adhered to copywrite restrictions. For the positive condition, five images were used with a high valence and high arousal rating (valence ranged from 6.208 to 6.49 (mean = 6.289), arousal ranged between 4.65 and 5.03 (mean = 4.885)). In contrast, five neutral images were used with low valence and low arousal (valence had a range of 2.598 and 4.029 (mean = 3.35) and an arousal range of 1.693 and 1.99 (mean = 1.867) (Kurdi, Lozano and Banaji, 2017). All images were displayed for three seconds each.

A practise activity consisted of memorising three letters and then solving a simple 2-step maths problem ((2x3)+1). For the main trial, an operational SPAN was used as this type of test is regarded as a reliable measure of working memory because it has been highly correlated with other cognitive assessments (*APA Dictionary of Psychology*, 2007). A shortened version of the operational SPAN, based on Foster's

et al. (2015) version, was used as the impact of the incidental emotion would have time limited effects. The experiment comprised of three blocks which allowed for the opportunity for potential errors. The first block presented a letter to be remembered, displayed for two seconds, and then a maths distractor question displayed for ten seconds or until an answer had been submitted (Unsworth and Engle, 2005). This was repeated a further two times before a page was displayed to input the three remembered letters. This was repeated with two further blocks of unpredictable length (Foster *et al.*, 2015) – five letters and then four letters. At the end, a debrief was displayed.

Procedure

A pilot study was conducted with five participants to ensure the experiment worked, that the test was accessible but also allowed for errors to be collected. It was identified that participants were exiting the experiment before the end, therefore modifications were made by putting prompts to continue at the top of the page. The experiment was presented online via Gorilla and participants could complete it using any device. Participants were presented with details of the study, the consent form and the option to click in a box to say that they agreed to proceed followed by a page to enter their age. To familiarise participants with the upcoming activity, they were presented with a practice trial of letters to remember and a maths question. Following this, participants were randomly allocated to either the neutral or the positive condition where they were asked to look at five images.

All participants completed the same operational SPAN test activity. The first block consisted of a letter being displayed for two seconds followed by a 2-step maths problem to solve within 10 seconds, then a further letter and maths problem and again a third followed by a maths question. The participant was then requested to type the three letters that they had remembered. This was repeated for a further two blocks of five letters with maths questions and finally four letters with maths questions. After each input from the participant, they were given feedback with a green tick if they were correct or a red cross if they were incorrect. All stimuli were presented in the same order as any practice effects would equally affect both groups. The number of errors made in remembering the letters were recorded out of a possible twelve errors. The errors made on the distractor maths questions were not

recorded. Participants were not aware that only the data from the memory aspect of the test was being recorded and not from the maths activities.

Objectivity was maintained throughout the experiment as all participants were unknown and anonymous (Harrison and Hewson, 2023a). Every effort was made to ensure that the experiment was reliable, as all participants completed the same test, in the same order with the only difference being the emotional stimuli they experienced (independent variable). However, as the experiment was completed remotely, it was not possible to control the environment of each individual and this may have led to other confounding factors (Harrison and Hewson, 2023b). It was important to ensure the validity of the experiment and that it was measuring working memory performance therefore the test was based on a validated operational SPAN (Foster *et al.*, 2015). The images had also been validated for emotional content with the amount of valence and arousal measured (Kurdi, Lozano and Banaji, 2017). Also, there are questions as to whether the study can be generalised as the sample was not reflective of the population (Harrison and Hewson, 2023a).

Data

In total 101 participants enrolled onto the experiment. Of these, 31 did not complete to the end and were therefore rejected. This resulted in the complete data for 70 participants whose data was extracted from the Gorilla software and relevant data was organised into a spreadsheet with the following information for each participant – participant ID, age group, emotional condition and number of errors. Two participants requested for their data to be withdrawn and eight were removed as they were out of the specified age range. Therefore, the study analysed the data from 60 participants. The data was coded to enable participants to be grouped into two age groups and two emotion groups.

As the groups were of unequal size, a Shapiro-Wilk test was conducted (Thompson, 2023) and reported that three groups were non-significant and therefore met the assumption that the groups were normally distributed. However, the older/positive group was significant and therefore not normally distributed. Three outliners were identified from this group and they were removed from the data. As the experiment was conducted online it was not possible to see how these participants conducted

the test and as they were higher error scores and further away from the mean. After removing these outliners from the older/positive group, it was still not normally distributed with a Shapiro-Wilk result of .018.

Results

A 2 x 2 independent factorial ANOVA on the data of 57 participants (M age = 37.13, SD = 8.882) was carried out to investigate the impact of age and positive emotion on working memory performance (see table 1 and figure 2). Levene's test was significant and therefore confirmed that the assumption of homogeneity of variance had not been met, F(3,53) = 6.130, p=.001.

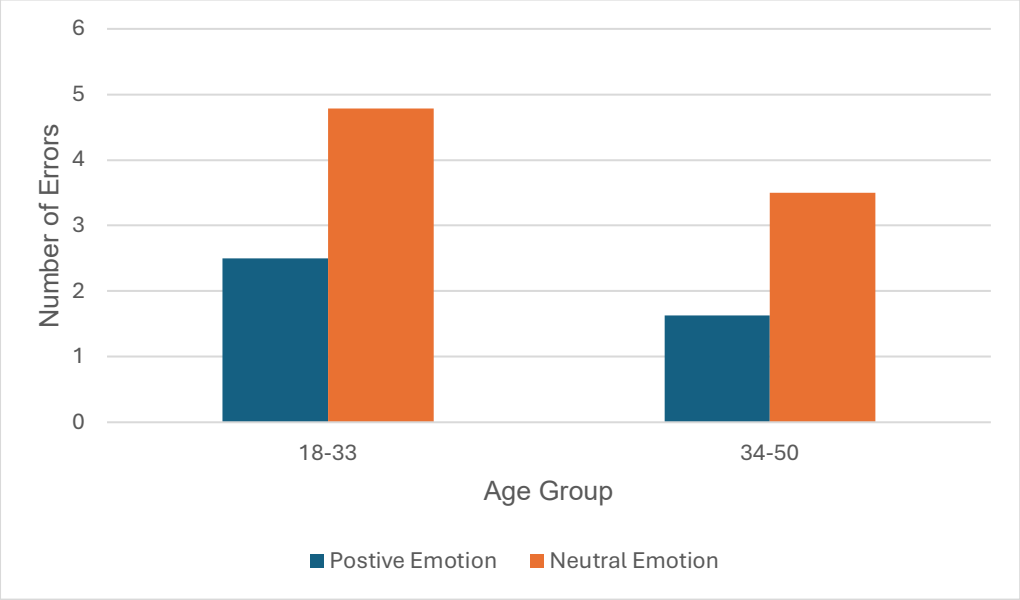
Table 1

Descriptive Statistics - Number of Errors for Age Group and Emotional Stimuli

	Positive Emotion			Neutral Emotion			Total		
	n	*M*	*SD*	*n*	*M*	*SD*	*n*	*M*	*SD*
Age 18-33	10	2.500	2.369	14	4.786	4.246	24	3.833	3.703
Age 34-50	19	1.631	1.571	14	3.500	3.032	33	2.424	2.450
Total	29	1.931	1.889	28	4.142	3.679	57	3.018	3.091

Figure 1

Number of Errors made on Working Memory Test for Emotion and Age.



No significant main effect of age was found ($F(1, 53)= 1.855$, $p = .179$, $\eta_p^2 = .034$) with a small effect size. There were slightly more errors made in the 18-33 age group (mean = 3,833, SD = 3.703) than in the 34-50 age group (mean = 2.424, SD = 2.450) therefore, this does not support the hypothesis that more errors would be made by the older age group. A significant main effect of emotional stimuli was found ($F(1, 53)= 6.897$, $p = .011$, $\eta_p^2 = .115$) with a medium to large effect size. There were more errors made in the neutral emotional stimuli group (mean = 4.143, SD = 3.679) than in the positive emotional stimuli group (mean = 1.931, SD = 1.889). This supports the hypothesis that positive emotion prior to completing a working memory test will lead to fewer errors. However, the interaction between emotion and age was non-significant ($F(1, 53)= 0.70$, $p = .793$, $\eta_p^2 = .001$) with no effect size. This does not support the hypothesis that positive emotion would have a bigger impact on older adults than younger adults (table 2). Estimated marginal means (figure 2) added further support to there being no interaction between age and emotion. The Kruskal-Wallis test reported that there was not a statistically significant difference between the groups in terms of the errors made in the working memory test, $H(2) = 3.426$, $p = .180$.

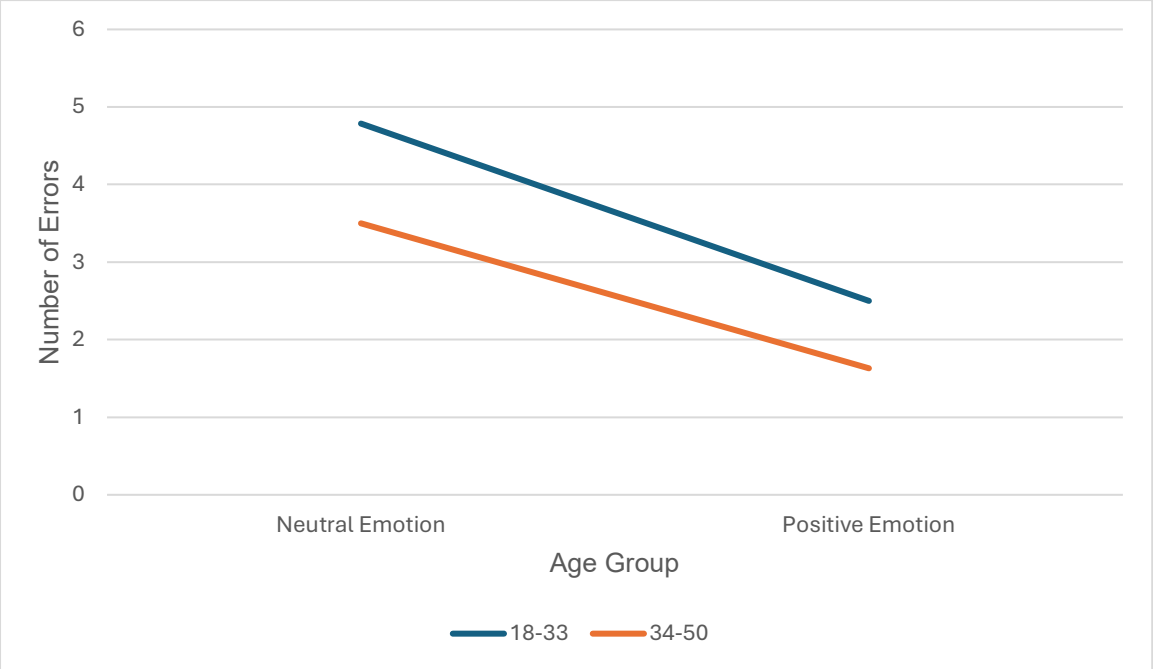
Table 2

Between Subjects Effect Table for Emotion and Age on Working Memory Performance

	(F(1, 53)	p	η_p^2
Age	1.855	.179	.034
Emotion	6.897	.011	.115
Age/Emotion	.070	.793	.001

Figure 2

Estimated Marginal Means of Errors Made.



Discussion

The current study found that fewer errors were made by the 34-50 age group than the 18-33 group which suggests that there was no difference in working memory performance on account of age. Research has shown a linear decline in cognitive function from early adulthood (Salthouse, 1996; 2010; 2019), therefore it was predicted that the younger group would have better working memory results than the older group. However, this study did not find a significant difference in working

memory performance based on age. If there has been any age related decline, working memory cognition may have been compensated for in other ways therefore adding support for the compensation theory and the plasticity of the brain (Reuter-Lorenz and Cappell, 2008). As the participants in the study were probably students it is likely that they would have experience of being cognitively active. Even so, Salthouse (2019) has acknowledged that there are some differing results for the mid age group which this study would seem to support. But he suggested that there are a number of factors that affect test scores for this age group, such as motivation, different stimuli and test methods as well as the effect of differing methods of analysing cognitive ability (Salthouse, 2019). As this study used a between-participants design, this would address a number of his concerns. Moreover, this study differed to the correlation studies of Salthouse as it grouped the participants into age groups. However, even with similar age groups, Kropotov et al. (2016) reported better working memory performance for the under 33 age group than for the 34-50 group which differs to this study's findings.

It was found that fewer errors were made in the positive group than in the neutral group and this study demonstrated a significant effect of positive emotion on working memory test scores for both age groups. This supports the hypothesis that encountering positive emotion prior to completing a working memory test will lead to fewer errors. This is consistent with previous research (Yang, Yang and Isen, 2013; Storbeck and Maswood, 2016) that found positive emotion improved cognitive control within working memory. However, this study was not able to answer whether the emotional effect was because of the biological factors of valence (Ashby, Isen and Turken, 1999; Yang, Yang and Isen, 2013) or arousal (Osaka *et al.*, 2013). As this study found that positive mood improved performance for both age groups despite any biological cognitive aging, motivational factors may offer explanations for improved performance with positive stimuli (Fredrickson, 2001; Gable and Harmon-Jones, 2010). Moreover, this study differed from others in that it used incidental emotion. It also had contradictory findings to that of Dodd et al. (2017) who concluded that for the emotional stimuli to be effective it needed to be relevant to the task, however the incidental positive emotion in this study was significant. Previous studies (Mammarella *et al.*, 2013; Ziaei, Salami and Persson, 2017; Mok *et al.*, 2019)

used integrated emotional stimuli which would have had continuous emotional impact, unlike the time limited influence of incidental emotional stimuli.

There was no significant interaction between emotion and age, and it was found that positive emotion did not impact the older participants (mean difference in errors between emotional stimuli = 1.632) more than the younger (m = 2.286). Positive mood does appear to have led to less errors in working memory performance, but older adults performed slightly better than the younger age group which suggests that there was no impact of age on positive effect. This does not support previous research by Mammarella et al. (2013), Ziaei, Salami and Persson (2017) and (Mok et al. (2019) who all found that there was a positivity bias for older adults during working memory tests when they encountered positive emotional stimuli. It was predicted that positive emotion would make a bigger impact on the older group of adults because of the evidence around compensation theory as the positive emotion would compensate for any cognitive decline (Reuter-Lorenz and Cappell, 2008). However, previous research looked at much older participants who would have experienced more age-related cognitive decline and emotional compensation may have been more relevant. As this study used mid-aged participants, it may suggest that emotional compensation is not yet being used to overcome any cognitive challenges.

There were a number of strengths to this research and every effort was made to guarantee the reliability and validity of the experiment by ensuring consistency in the test and in its use of materials. As it was a between-participants design, any differences in test results could not be due to practice effects (block) which has previously been suggested by (Salthouse, 2019) to explain mixed cognitive test results for the mid-age group. A further strength of the research was that it considered a different age group to what is usually studied in either experiments concerned with aging and those that look at emotion. As the 34-50 age group is often overlooked, this study can potentially add to the field of research into the early stages of age related cognitive decline and how emotion can influence working memory performance. This study forms the basis for suggesting further directions of study for researchers interested in the effects of emotion and cognitive aging.

There were some statistical limitations to the study as the potential number of errors was low and the number of participants in some groups was also small. Levene's was significant and indicated that there was not a significant difference between variances of the groups (Harrison, G. and Hewson, C., 2023b). Furthermore, the Shapiro-Wilk result found that the 34 to 50 group that encountered the positive emotion was not normally distributed (Thompson, 2023). There were also potential limitations to the effects of the emotional stimuli. As the experiment used incidental emotional stimulus this would have had time limited effects and as the experiment was completed remotely, it was not possible to establish if it created a positive mood or for how long it lasted. Moreover, there was no account for individual differences in emotional responses nor any cognitive differences. Furthermore, how motivated individuals were to complete the task well and participants' life experiences may all have had an impact on test performance. In designing this study, the utmost care was taken to control potential confounding variables, however it remains unclear whether the pattern of results observed is due to the effects of mood and age or to individual differences.

This study concluded that positive emotion improved working memory performance but it did not look to the causes. As there was no significant difference for age, despite cognitive aging, it may point to motivational aspects of emotion that create the positive effect rather than biological. Therefore to build on this study, future researchers could investigate how the motivational aspect of emotion effects working memory for different age groups by comparing low and high motivational stimuli with a particular focus on the mid-age group. Future studies could also consider replicating the experiment in observational conditions to control for other factors that may have influenced performance. To improve statistical accuracy, any future experiments could look at either increasing the number of participants or using the full operational SPAN test rather than a shortened version to allow for a higher number of errors to be analysed.

Conclusion

To conclude, the present study investigated the impact of incidental emotion on working memory performance and whether the impact was greater for older participants. Despite contradictory research, there was no difference in working

memory performance for age. However, the results revealed that positive emotion significantly improved working memory performance regardless of age. As working memory is an essential cognitive ability needed in everyday life and in the workplace, these findings can help us to understand the influence of positive emotion in improving cognition for all. Building on this study, future research could further investigate how the motivational aspects of positive emotion effects working memory and how this differs as the brain ages.

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