Cognitive control in affective contexts in adolescence

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Abstract

Adolescence is characterised by a period of fluctuating and intense emotions to social stress. During this time, their Working Memory (WM) capacity and ability to retrieve memories increases with cognitive development, making it an essential mechanism for making decisions within the social world. We currently know little about how WM capacity in affective contexts is processed in adolescents with varying mood. A visuospatial search and written storage task were performed in the presence of either neutral or negative distractor images in a large sample (n=425) of adolescents, with data collected from the baseline testing of the 'My Resilience in Adolescence' (MYRIAD) project. Overall, performance across both affective conditions increased as a function of age and IQ, and we report a small magnitude of the effect for affective information in WM capacity. There was no support for this effect being modulated by symptoms linked to depression. Implications for these findings contribute to the growing body of WM literature showing little support for the differential impact of socio-affective information for adolescents with varying mood.

1.0 Introduction

Cognitive control refers to a collection of mental processes that guide thought and behaviour in accordance with internally generated goals (Diamond, 2013). Cognitive control is effortful; it is invoked when necessary to override unwanted behavioural responses or to manage undesired thoughts memories or feelings (Koechlin, Ody, & Koyneiher, 2003). For example, studying for exams (goal-directed behaviour) would invoke cognitive control to ignore distracting (goal-irrelevant) information and temptations.

One way of operationalising cognitive control is via measures of working memory capacity (WMC) – the ability for short-term storage of information in the face of competing cognitive demands (Conway et al., 2005; Engle, 2010; Engle & Kane, 2004). For example, the ability to remember lists of words encoded in the context of competing tasks such as a set of simple maths problem (ref).

There has been a significant interest for researchers to identify the point where cognitive control functionality becomes overwhelmed by the goal-irrelevant distractors. Researchers commonly opt for affectively-laden stimuli that pertain to real-world information to test the boundaries of cognitive control (hereby termed 'affective control'). This was evident in a recent large-scale meta-analysis of 164 studies (N=7,410) that showed adults presented mainly deleterious effects in their WM performance when the information was affectively-laden, with memory recall worse during a negative compared to neutral conditions. Interestingly, the authors reported the effect sizes seen on a behavioural level was disproportionate to the larger effect sizes found on a neural level, indicating the presence of affective material requiring frequent recruit of neural regions to invoke affective control. In other words, the automatic attention-grabbing properties of negative information are hugely demanding on the brain for applying affective control, which has the potential for impairing cognitive performance in everyday life.

Despite significant evidence for the existence of affective control, it is worth highlighting the equivocal behavioural findings in Schweizer et al. (2019) meta-analysis. The behavioural studies ranged in their effect sizes, which is likely due to the range of affective stimuli used in each affective WM condition. Researchers commonly opt for affectively-laden stimuli that pertain to real-world information that is more or less relevant to all participants (e.g. survival motives). Whilst the threatening information may interfere with the perceptual and cognitive systems for affective control, their modulating effect on current task performance is proposed to be limited – this is termed soft prioritization in the Dual Competition Framework (DCF; Pessoa,2009). Therefore, it is unsurprising that the choice of utilizing low-threatening stimuli would lead to small to negligible effects, with traditional researchers often underappreciating or misinterpreting such results as they focus on significance values (Funder & Ozer, 2019). Researchers working on task manipulation with affectively-laden stimuli must be aware of such pit-falls and allow readers to come to their own conclusion when interpreting effect sizes.

Why is mental health research focusing on the cognitive systems for maintaining affective control? We know that affective control can be compromised in affectively-laden contexts as intrusive thoughts, feelings or ruminative patterns interfere with functionality. How affective control systems function are likely to differ between individuals, with poor affective control differentiated between psychologically healthy individuals and those with a mood disorder. This was evident in the meta-analysis mentioned earlier (Schweizer et al., 2019), as adults with a wide range of mental health problems including depression, anxiety, schizophrenia and eating disorders showed greater impairment of WM in the presence of affective material relative to healthy adults. This was also apparent in a WMC paradigm; impaired performance was reported in healthy adults (Garrison & Schmeichel, 2019), but particularly adults with dysphoria (Hubbard, Hutchison, Hambrick & Rypma, 2016; Hubbard, Hutchison, Turner, et al. 2016), Post Traumatic Stress Disorder (PTSD; Schweizer & Dalgleish, 2016), and depression (Joormann & Gotlibb, 2008; De Raedt & Koster, 2010; Snyder, 2013; Kertz, Belden, Tillman & Luby, 2016; Hofmann, Sawyer, Fang & Asnaani, 2012). Although recent studies propose affective WM performance can be maintained across fluctuations in mood

(Berman et al., 2011; Bertocci et al., 2012; Foland-Ross et al. 2013; Joormann & Gotlib, 2008; Joormann et al. 2011, 2010; Tavitian et al. 2014; Yoon et al., 2014; Schweizer et al. 2018). Arguably, soft prioritization of the affective stimuli may have led to small effects in their findings, as mentioned easlier.

Despite convincing evidence pointing to impaired affective control as a transdiagnostic mechanism associated with poor health, little research has focused on this as a pre-clinical marker during development. Adolescence has been characterised as a sensitive period during which an individual is particularly susceptible to the influence of socio-cultural information (Blakemore & Mills, 2014). During adolescence, social orientation towards peer approval becomes increasingly crucial for development, with negative social experiences being perceived as aversive or stressful (Blakemore, 2019; Crone & Dahl, 2012; Steinberg & Morris, 2001). It is during adolescence that the majority of mental health problems typically occur, with 50% of adults with psychiatric disorders reporting their first onset by the age of 14 years (Kessler et al. 2005). This may signal a problem for adolescents in everyday mental operations, as critical amounts of cognitive resources are taken up in dealing with the socio-emotional thoughts that, although intricately linked to their problems, may not be relevant to the task at hand (Mason et al., 2007).

Despite all evidence pointing to adolescence as a key period for understanding the role of compromised affective control in later mental wellbeing, fewer than 10% of research into affective WM include children and/or adolescents, demonstrating how underresearched the area is (Schweizer et al., 2019). Little is known about the degree to which affective control maintains functionality in adolescence as the developmental trajectory appears to not be uniform (for review, see Schweizer et al., 2020). However, across the three facets of affective control (inhibition, updating and shifting), poor affective control is associated with more mental health problems in adolescents (Kilford et al., 2015; Ladouceur et al., 2013; Mirabolfathi et al., 2020; Schweizer, Parker et al., 2019). Understanding whether impairments in affective control occur in a particular sub-set of adolescents may be crucial for explaining why some adolescents are less equipped to deal with, and behave appropriately, in future novel situations (Monks *et al*., 2005; Shallice *et al*., 1996). Therefore, the current study investigates the interplay of these factors – affective control, socio-affective information, and mental health – in typically developing adolescents.

The present study

This study aims to investigate whether impairments in affective control is associated with self-reported low mood in adolescents. A WMC paradigm with task-irrelevant distractors containing affective stimuli that are salient to adolescents was chosen. In particular, socially stressful scenes were chosen as our affective stimuli, as previous work has shown this to disrupt the cognitive processes for executive functioning (Baumeister et al., 2002; Williams et al., 2000; Fuhrmen et al., 2019; de Wilde et al., 2016; Holmes et al., 2016; Curci et al., 2013; Xu et al., 2018). Given that peer victimisation and bullying are relatively common experiences in childhood and adolescence, with 54% of secondary school and college students experiencing some form of bullying (The UK annual bullying survey, 2017). We believe these real-world scenarios are relevant to our adolescent sample. Finally, the Affective Picture Span Paradigm (APSP, Schweizer & Dalgleish, 2016) was used to operationalise affective control, as the affectively-laden stimuli can be transposed onto the background as our task-irrelevant distractors. Given that pictures convey a better affective meaning than an elicited response over sentences (Winkielman & Gogolushko, 2018), it was clear that the APSP was the appropriate WMC task for this study.

Data from the My Resilience in Adolescence (MYRIAD) project, a large-scale study investigating mindfulness's cognitive mechanisms, was used for the present study. The MYRIAD sample consists of over 500 adolescents with no history of a mental health disorder, thereby increasing the probability of identifying an at-risk sample of adolescents from the local community. Additional information such as age and IQ will provide a larger picture of the relationship between demographic factors on WMC performance. The main findings will attend to the accuracy of the overall WMC performance, with further analyses exploring changes in increasing cognitive load reported in the supplementary materials.

We predicted the following:

1) WMC in the negative condition will be poorer than in the neutral condition, in line with previous evidence (Schweizer et al. 2019).
2) Overall performance (i.e. across both conditions) of the WMC task will improve with age and intelligence across the whole sample.
3) The self-reported low mood ('at-risk') group will show a greater affective WMC effect compared to the healthy ('low-risk') group, with those lower in mood showing a greater reduction in performance as a function of negative background images.

2.0 Methods

2.1 Participants

A total of 568 participants (aged 11-18 years) were recruited from 12 schools and one college in Greater London and Cambridgeshire, U.K.. Participants were recruited as part of a study investigating the mechanisms of mindfulness training in adolescence which involved a range of other cognitive tasks and questionnaires as well as those reported here (MYRIAD; https://osf.io/d6y9q/). The MYRIAD project was advertised through local secondary schools, with participants recruited in school assemblies (all year groups: 7 to 11). Participants were offered the opportunity to take part with two exceptions: (i) self-reported diagnosis of neurodevelopmental, neurological disorder or learning difficulties; and (ii) any self-reported history of a mood disorder. In total, data from 425 participants aged 11.50-18.5 years (M= 14.42, SD=1.73) were available for full analysis, with data from 143 participants set aside.

Participants were removed from the main analysis because either they did not complete both conditions of the affective WM task (n=24), they were inadvertently allocated an incorrect version of the counterbalanced task (n=44),the task failed during testing (n=22), they had a SEN requirement (n=1), they failed to meet the attention target detection rate threshold for the WMC task (n=37; see *The Affective picture span paradigm* below for more details). Finally, demographic information including age (n=2), IQ (n=7), gender (n=1) and self-reported mood (n=5; see *Mood measure* below) were missing and subseqeuntly set aside from further analysis.

2.2. Measures and Materials

2.2.1. Mood measure

Center for Epidemiological Studies Depression Scale (CES-D), Radloff 1997.

The CES-D is a 20-item questionnaire asking about feelings or behaviours associated with depression (e.g. poor sleep, poor appetite, feeling lonely) during the past week, using a 4-point scale ranging from 0 (Rarely or None of the time/ for less than 1 day)' to 3 (Most or Almost All of the time/5-7 days). A total score ranges from 0-60 with higher scores indicative of greater depression symptomatology. The CES-D provides cut-off scores for those deemed to be 'at-risk' (≥19) of depression, with good sensitivity and specificity and high internal consistency (Lewinsohn, Seeley, Roberts, & Allen, 1997). The CES-D was used here for to allow comparison of WMC performance in adolescents in the 'low risk' and 'at risk' ranges for depression.

For CES-D questionnaires that contained <20% missing items, values were replaced by the individual scale mean. When >20% of items were missing (n= 5), those particpants were set aside from these analyses.

2.2.2. Fluid Intelligence

Cattell Culture Fair Intelligence Test (CFIT; Institute of Personality and Ability, 1973)

The CFIT is a non-verbal measure of fluid intelligence involving a series of questions asking about the relationships between figures and shapes. The CFIT consists of four subtests that must be completed under timed conditions: sequence analysis (6 minutes), oddity identification (6 minutes), matrix completion (4 minutes) and a reasoning task (3 minutes 30 seconds). For each question, participants select one of four options provided. The total score is then standardised to the age of the participant (*M*=112.78, *SD*= 17.09), with higher scores presenting higher levels of fluid intelligence. The CCFI was used here to allow us to relate non-verbal intelligence to WMC performance.

2.2.3. The Affective picture span paradigm (APSP)

The APSP used here was adapted from a version used in a previous study in adults (Schweizer & Dalgleish, 2016). The task comprised two cognitively engaging components. The first is a target (storage) task, where participants are told to learn and retain a set of words, presented 1 word per trial in blocks of 2-5 trials and superimposed upon a background image (see Supplementary Material ST1 for the list of words used). The second component is the operation (distractor) task, which is performed simultaneously with the target task, and involves a varying number of shapes (pink squares) appearing over the same background image on each trial, before and after the target word is presented, with the number of shapes varying in the range 4 to 6 across trials. Participants are instructed to count and report the number of shapes within a given trial at the same time as memorising the word on that trial.

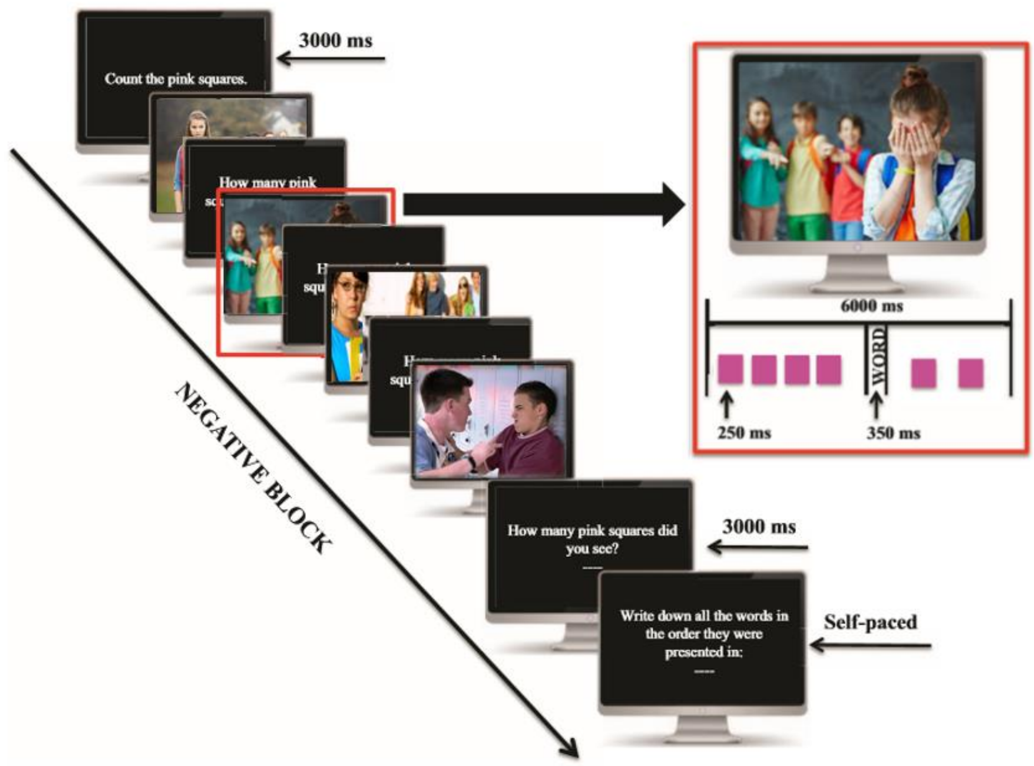

Figure 1. A sample 4-trial block for the Affective Picture Span Paradigm (APSP) for the APSP-Negative condition, adapted from Schweizer and Dalgleish (2016).

At the start of the trial, 2-3 shapes popped up over the background image for 250 ms (see Figure 1). Next, the to-be-remembered word for that trial appeared for 150 ms over the image. Finally, the second set of 2-3 shapes appeared (duration: 250 ms). The numbers of shapes in a given trial (maximum of 6) was randomly set before and after the presentation of the target word. The screen, including the image, then cleared, and participants were prompted to enter the number of target shapes they had seen using the numbers on the keyboard (1750ms).

Trial blocks comprised between two and five trials, with each trial lasting 600ms. At the end of a trial block, participants were asked to type as many of the presented words as they could remember in the temporal (trial) order in which they had been presented. There was no time restriction on recall. The recall screen presented one blank box per word so participants to cue participants on how many words had been presented.

Task valence was manipulated by presenting background socially-relevant images that were either emotionally neutral (APSP-Neutral condition) or emotionally negative (APSP-Negative condition) in content. Images depicting negative social-contexts (such as bullying or social exclusion) were rated by an independent group of adolescents for: (i) emotional arousal; and (ii) negative valence, using Self-Assessment Manikins (SAM, Geethanjali *et al.* 2017). Significant differences in valence and arousal were found between the emotionally neutral and negative backgrounds (see Supplementary Material ST2).

Each block length (2-5) was presented twice in each affective condition (negative, neutral), giving a total of 56 trials over 16 blocks. The neutral blocks and the negative blocks were divided into two sets of eight with the presentation order counterbalanced across participants. After completing the first set of eight blocks, participants had a brief break before they continued with the second set. The whole task took approximately 15 minutes and was programmed using E-prime® 2.0 SP2 and presented on 13-inch laptops. Before the task, participants read the instructions on the screen and completed two practice trials. Participants had the opportunity to ask any questions before the task commenced.

Adjustments were made to the adult version of the APSP (Schweizer & Dalgleish, 2016) to reduce floor effects in this younger population: (i) The range of block sizes in the target component was reduced to between 2-5 trials, (ii) only one type of target shape at a time was used for the operation component, (iii) the recall screen contained slots matching the number of words presented, (iv) the proportion of operation task trials that needed to be correct for the particpant's data to be reatained (the Attention Target Detection Rate; ATDR) was reduced to 42.75% (see Supplementary Material for further details). The task was also modified to encourage group-based data collection through the use of written recall (rather than verbal). This minimised peer distraction and encouraged individuals to complete the task in exam-style conditions.

To compute total WMC scores for the APSP-Negative and APSP-Neutral conditions, we calculated the proportion of all words that were recalled in the correct position (Conway et al. 2005), summed across the 8 blocks in each condition. We then computed a WMC-index which was computed in percentage terms as the increment in APSP performance for the APSP-Neutral condition relative to the APSP-Negative condition. Increasingly positive WMC-indices therefore indicate the extent to which participants performed better in the APSP-Neutral condition. APSP scores for each valence condition were also computed separately for each block size such that each participant had mean APSP scores for neutral and negative trial blocks of sizes 2-5 (see Supplementary Materials).

2.3. Procedure

The study was approved by the Cambridge University Psychology Research Ethics committee and UCL Research Ethics Committee. Informed consent from parents and assent from participants was obtained for participants under 16 years old, and informed consent was obtained for participants over 16 years old.

The majority of testing took place in groups (comprising between 2 and 15 participants) on individual laptops, guided by a team of two to four researchers . Testing took place at either the participant’s school or at the MRC Cognition and Brain Sciences Unit. One participant was tested alone as they missed the group session. Due to testing constraints, testing sessions were split over two days for four groups of participants (n=46). For each session, laptops were spread out across the room to minimise distraction and to maintain confidentiality. The present study was part of a series of tasks within a three hour session, with the present study taking 30 minutes in total.

Participants were compensated £15 in vouchers for taking part. Following the end of the study, participants were debriefed and informed about the study rationale.

3.0 Results

Participant characteristics

Descriptive data for 425 participants whose data were analysed are described in Table 1.

Characteristic	n (%) / Mean (SD)
Sociodemographic	
Age (years; mean, SD), range: 11.2-18.05	14.42 (1.73)
Gender (n, %)	
Female	284 (66.8)
Male	141 (33.2)
Fluid Intelligence (mean, SD), range: 76-160	112.78 (17.09)
Mental Health	
Depression (CES-D; mean, SD), range: 0-56	17.44 (10.77)
Low risk (n,%)	268 (63.1)
At-risk (n,%)	157 (36.9)

Table 1. Participant characteristics (n=425). Note. Cell size (n) and percentages (%) are given for categorical variables and means and standard deviations (SD) for continuous variables. Based on the analysis sample (n=425). CES-D = Center for Epidemiological Studies – Depression measure. IQ = standardised scores of the Cattell Culture Fair Intelligence Test.

3.1. APSP performance

3.1.1. Overall effect of affective condition

In line with our first hypothesis, a paired t-test revealed a significant difference across all participants in performance between the APSP-Neutral and APSP-Negative conditions, $t(424)=2.79$, $p=.006$, $d=0.13$, with participants on average recalling a higher proportion of words in the correct order in the APSP-Neutral (M=.76, SE=.01) condition than in the APSP-Negative (M=.74, SE=.01). Analysis of performance across conditions as a function of block size is presented in the Supplementary Materials.

3.1.2 Effects of Age and IQ on APSP performance

In line with our second hypothesis, APSP performance for both affective conditions increased with both age and fluid intelligence scores across the whole sample (Figure 2). Simple linear regressions showed that age was a significant predictor of performance in both the APSP-Negative ($F(1,423)=14.72$, $p<.001$, adjusted $R^2=.031$) and APSP-Neutral ($F(1,423)=10.67$, $p=.001$, adjusted $R^2 = .022$) conditions. Similarly, intelliegnce significantly predicted performance in for both the APSP-Negative ($F(1,423)=30.32$,$p<.001$, adjusted $R^2=.065$) and APSP-Neutral ($F(1,423)=37.81$,$p<.001$, adjusted $R^2=.079$) conditions.

A linear regression using WMC-index showed that neither age ($F(1,423)=.23$, p=.63, adjusted $R^2=.002$), nor IQ ($F(1,423)=.67$, p=.41, adjusted $R^2= .001$) predicted WMC-Index scores; ie., the difference in WMC performance between the neutral and negative conditions.

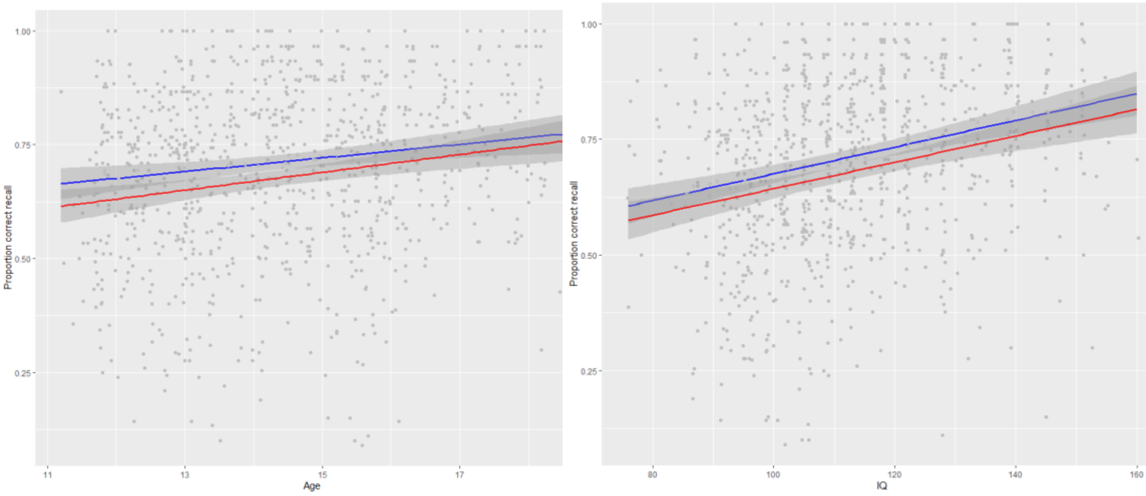

Figure 2

Scatterplots, overlaid with lines of best fit, showing relationships between age (left) and IQ (right) and APSP scores for the Negative (red) and Neutral (blue) task conditions.

3.1.2. Effects of depression status on APSP performance

We used the cut-off of 19 on the CES-D to create 'low risk' and 'at risk' Depression Groups and descriptive information and inferential statistics for the two groups are presented in Table 2.

	CES-D: 'low risk' (*n*=268)	CES-D: 'at risk' (*n*=157)	*t (df)*	$X^2(df)$	*p*
Age (Mean, SD)	14.25 (1.68)	14.72 (1.78)	2.69 (423)	-	.007
Gender (n female, %)	160 (59.7)	124 (79.0)	-	16.60 (1)	<.001
IQ (Mean, SD)	112.95 (17.09)	112.49 (17.15)	0.26 (423)	-	0.79
CES-D (Mean, SD)	10.79 (4.62)	28.79 (8.54)	28.19 (423)	-	<.001

Table 2. Demographic and mental health characteristics for the 'low-risk' and 'at-risk' Depression Group, based on the Centre for Epidemiological Studies–Depression (CES-D) cut-off score of 19.

As expected, the groups significantly differed in terms of their CES-D score. There was also a significant difference in age, with participants in the at-risk group being slightly older on average. In addition, the at risk group contained a significantly larger proportion of females. Subsequent group comparisons therefore included age and gender as covariates.

Performance on the APSP across task conditions (after adjusting for age and gender for the two depression groups) is presented in Figure 3.

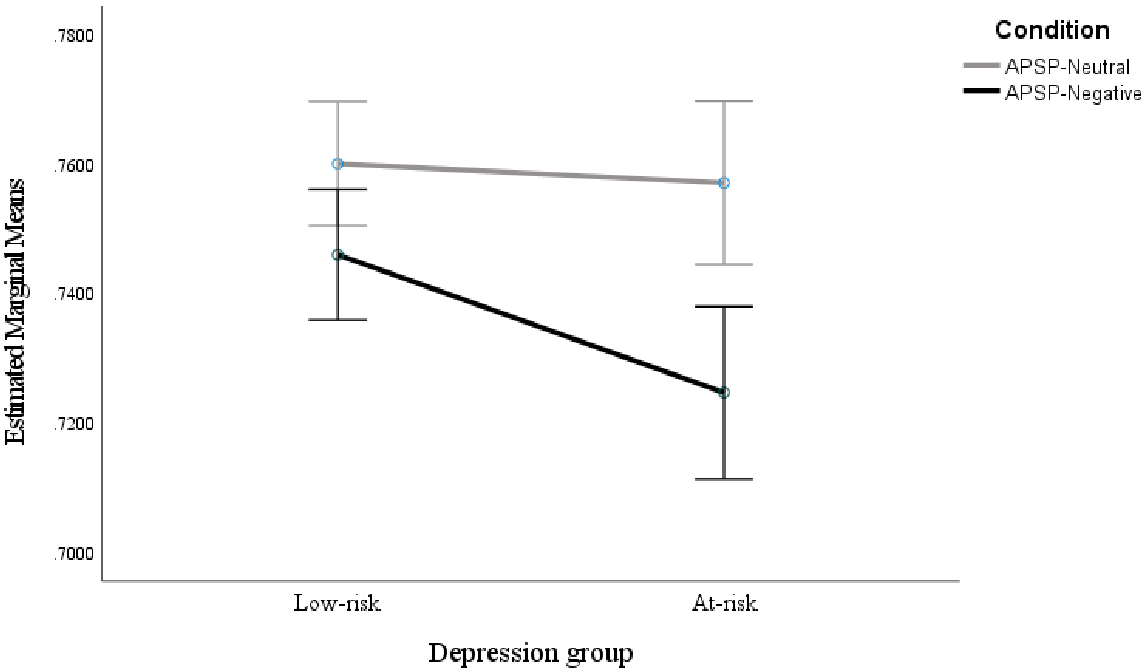

Figure 3. Estimated marginal means (adjusting for age and gender) for the two depression groups ('low-risk' versus 'at risk') across the APSP-Negative and and APSP-Neutral task conditions (averaged across load blocks). Error bars= 1 SEM.

A two-way Depression Group by APSP Condition, mixed ANCOVA, with age and gender entered as covariates, revealed no significant main effect of Depression Group (F<1), nor of

APSP Condition (F(1,421)=1.42, p=.23, η_p^2 =.003), nor a significant Group by Condition interaction (F(1,421)=1.34, p=.25, η_p^2 =.003). Analyses investigating the effects of task load (block size) are presented in the Supplementary Materials.

4.0. Discussion

This is the first large scale study to investigate affective control in adolescents. In line with the first hypothesis, WM capacity in the negative condition was significantly reduced compared to the neutral condition. Meaning, the socio-emotional information from the negative condition recruited greater affective control away from WM storage, thus impacting memory recall performance. This finding is consistent with a similar WMC paradigm with a mature student community sample (Schweizer & Dalgleish, 2016), suggesting that the automatic attention-grabbing properties of negative information can impair cognitive performance in adolescents everyday life. This builds on previous findings within the literature that have shown adolescents are hypersensitive to social information for detecting threats for early avoidance (Blakemore & Mills, 2014; Blakemore, 2019; Foulkes & Blakemore, 2016). Here, we have shown that (overall) this could be expressed by the lack of affective control mechanisms for disengaging from goal-irrelevant distractors from the social environment. This has consequences within a contemporary environment (such as school playgrounds where low-risk distractors may occur) when the lack of affective control could obstruct goal-directed behaviour (such as studying for academic success).

Although the effect size between the overall sample's affective conditions was small to negligible (d=.13), these were expected. These small effect sizes are realistically and correctly estimated, especially within the field of social psychology when the magnitude between affective conditions is less obvious (Funder & Ozer, 2019). As pointed out in the DCF, the affective stimuli's soft prioritisation will produce relatively minor effects on task-irrelevant stimuli (Pessoa, 2009). Therefore, to understand the strength of the effect, it would be necessary to understand the underlying processes that are known to be disrupted on a neural level, which have been known to show large dissociable effects in affective WM tasks (Schweizer et al., 2018). Thus, synergising behavioural with neural data will help understand the degree of effect for affective WMC in adolescence.

In line with our second hypothesis, we report an upward linear trend for both WMC conditions with increasing age and IQ scores. These findings support a growing body of literature indicating the processing efficiency for cognitive control requires higher mental intellectual activity (Chen et al. 2019; Darki et al., 2014), and brain maturity (Blakemore & Mills, 2014; Darki et al., 2014; Schweizer et al. 2020; Tamnes et al., 2010; 2013). Indeed, individuals with low IQ often struggle with highly demanding tasks due to their limited information processing capacity, despite a clear understanding of task instructions (Duncan et al., 2008). This 'goal neglect' is greatly influenced by the task complexity and one's level of attention, which requires greater recruitment of the fronto-parietal network (Duncan et al., 2008; Kane et al., 2002). Although this goes beyond this paper's scope, it is possible that the frontal-parietal network's developmental trajectory may be mediating trends reported for increasing age and IQ on WMC performance.

Whilst age and IQ predicted performance in both WMC conditions, neither predicted the effect of affective WMC (WMC-index). Instead, we show affective control appears to be maintained across age and IQ. Our findings go against previous work that has shown any particular age range (i.e. younger adolescents) are particularly susceptible to the socio-affective information interfering with WM accuracy (Fuhrman et al. 2019). Nor do we report differences in affective control between adolescents with high or low IQ , despite previous work showing higher IQ is associated with greater cognitive control abilities in adults (Checa & Fernandez-Berrocal, 2015). Any effects may be hindered by the soft prioritisation of the emotional stimuli, or emotional intelligence could have been a far more suitable measure than the CFIT used here (Megias et al. 2017). Nevertheless, it appears that the affective control system is maintained across adolescence with varying age and IQ, indicating another variable could better explain the effect reported.

In contrast to our third hypothesis, we report the effect of affective WM capacity was maintained in adolescents with low mood. This finding supports the growing body of literature showing negative information does not impair WM accuracy in adults with depression (Berman et al., 2011; Bertocci et al., 2012; Foland-Ross et al., 2013; Joormann & Gotlibb, 2008; Jormann et al., 2011, 2010; Ladoucear et al., 2005; Levens & Gotlib, 2009, 2010; Tavitian et al., 2014; Yoon et al., 2014; Schweizer et al., 2018). Based on this study's results, our findings in adolescents with varying mood also support this view.

Several factors might contribute to the findings. First, as mentioned previously, we expected small effect sizes in the overall sample due to the soft prioritisation (Pessoa, 2009; Funder & Ozer, 2019). Therefore, to report any statistical differences between mood groups will be harder to elucidate with such small effect sizes. This is especially the case for adolescents with an undiagnosed mood disorder, as they may not have developed the same obvious impairments seen in adults with clinical depression (Allott et al., 2016; Schweizer et al., 2019).

The second explanation of why WM deficits were not reported in our ‘at-risk’ mood group may be the affective information not being salient for distraction. The choice of affective material in this study was socially threatening (i.e. bullying, social exclusion) and normal in school settings, with 54% of secondary school and college students experiencing some form of bullying (The UK annual bullying survey, 2017). In Schweizer & Dalgleish (2016), the choice of affective material for the community sample were uncommon real-world scenarios (burnt victims, street violence, animals under surgery). Arguably, both affective materials have survival relevance (i.e. heightened response to threatening scenes override the executive processing system). However, exposure to socially threatening scenes could desensitise the adolescent population. Although the negative and neutral stimuli were checked before testing for valence and arousal, it is not clear if adolescents at-risk of depression perceived the socially threatening cues particularly distressing. This could have been addressed in the form of ratings after the task, which future researchers should consider.

Finally, there is a broader discussion about whether poor WM capacity is indeed a sensitive marker for identifying depression in adolescents. In a model identified in Huang-Polloc et al. (2017), WM deficits represent a cognitive liability associated with the development of common and discrete dimensions of psychopathology. In particular, WM only correlated with general externalising domains (such as inattention, hyperactive or impulsivity), and not internalising domains. Arguably, the CES-D self-reports for identifying depressive traits used here focus on the internalised negative thought processes (e.g. CES-D items ‘I thought my life had been a failure’, ‘I could not get going’). Such findings indicate the need to investigate the dimensional liabilities that influence the development of mental health problems, rather than focus on the traditional cut-offs in a single questionnaire.

Several interesting findings arise from the present study for future researchers to note: over one in three adolescents in our sample are considered at-risk of developing depression, and one in ten has a probable caseness for depression. This is amongst a community sample with no history of depression experiencing their first mood disturbances and have not sought clinical advice. Primary mood disorders typically occur around the age of 15 years (Kessler, 2005), which is the average age of the participants reported in this study. Whilst it is not reported here that affective WMC is affected in adolescents with low mood in the adapted version of the visuospatial paradigm, future studies should still focus on broad impairments found in multiple aspects of executive functioning (Joormann & Gotlibb, 2008; De Raedt & Koster, 2010; Snyder, 2013; Kertz, Belden, Tillman & Luby, 2016; Hofmann, Sawyer, Fang & Asnaani, 2012). Researchers should note the figures within this community sample and consider potentially fruitful strategies to detect mental health problems. For example, multiple tests of executive functioning should be run to assess convergent validity, which could come as different tasks, stimuli dimensions and sets of cues that should increase the chances of identifying neurocognitive impairments that are an early marker for depression (Boogert et al., 2018).

There are limitations in the present study that merit consideration when evaluating the current results. Data collection came from schools based in London and Cambridgeshire. Without a better understanding of the schools' sociodemographic information and student socioeconomic status, individual differences investigating the social processes cannot be fully explored. Another potential issue is the impact of running group-based data collection in schools using tasks screening for attention. Peer presence has been shown to affect adolescents' decision-making compared to any other age group, indicating the environmental factors could effect task performance (Chein et al. 2011). Whilst the current study followed a strict protocol to minimise environmental distractors during testing (e.g. separate students and work in exam-style conditions), future work should carefully consider the impact of background information that may interfere with the participant. Another potential issue was the transition to written (versus verbal) recall of the storage task. The APSP used here is an adapted version designed for group-based testing, however, this may be disadvantageous for those with writing difficulties. We addressed this issue by choosing words with a young age of acquisition (<11 years) and recruiting participants with no learning disabilities. Task adaptation also included adjusting for the ATDR as the average was below the cut-off seen in typical complex span tasks (Conway et al. 2005). Given that WMC does not reach maturity until later adult life (Isbell, 2015), the authors felt it was justified to reduce the ATDR to a reasonable cut-off and apply additional measures to ensure data integrity. A final limitation was the lack of ratings for the affective background images. Ratings for valence and arousal were collected from an independent group of adolescents that may hold different views in what is affective. Post-ratings on the affective stimuli should be checked after the study to ensure the information was adequate.

In conclusion, affective WMC containing negative social information was reduced in the overall adolescent sample, in line with findings in a recent meta-analysis (Schweizer et al., 2018). WMC increased as a function of age and IQ, but affective control was maintained. Finally, after identifying our Depressed Groups, the effect of affective social information within the WMC task was maintained across mental health statuses. Future research should investigate the individual differences in WMC performance in terms of small effects sizes, the range of cognitive loading, and the choice of affective stimuli for identifying the early markers of depression in adolescents.

5.0. References

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