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Affective Control in Adolescence: The Influence of Age and Depressive Symptomatology on Working Memory

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People exhibit marked individual variation in their ability to exercise cognitive control in affectively charged situations. Affective control is typically assessed in laboratory settings by comparing performance in carefully constructed executive tasks performed in both affectively neutral and affectively charged contexts. There is some evidence that affective control undergoes significant improvement throughout adolescence, though it is unclear how adolescents deemed at risk of developing depression exercise affective control despite poor affective control being identified as a contributing factor to ongoing mental ill health in adulthood. The present study therefore investigated affective control in a large (n = 425) sample of adolescents (aged 11–18 years) collected from 2016 to 2018. A simultaneous visuospatial search and written storage working memory (WM) capacity task was carried out to examine affective control, using affectively neutral and affectively negative social images as the task-irrelevant distractors. Overall, WM capacity increased as a function of age across both affective conditions. Moreover, we report a significant difference between affective conditions, with WM capacity slightly lower during trials with affectively negative social

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The signatory for the MYRIAD team is Tim Dalgleish. The MYRIAD team comprises Saz Ahmed of University College London; Susan Ball of University of Exeter; Marc Bennett of University of Cambridge; Nicola Dalrymple of University of Oxford; Darren Dunning of University of Cambridge; Katie Fletcher of University of Oxford; Lucy Foulkes of University College London; Poushali Ganguli of King's College London; Cait Griffin of University of Cambridge; Kirsty Griffiths of University of Cambridge; Konstantina Komninidou of University of Oxford; Rachel Knight of University of Cambridge; Suzannah Laws of University of Oxford; Jovita Leung of University College London; Jenna Parker of University of East Anglia; Blanca Piera Pi-Sunyer of University College London; J. Ashok Sakhardande, Jem Shackleford, and Kate Tudor of University of Oxford; Maris Vainre of University of Cambridge; and Brian Wainman of Plymouth University. These individuals have worked across the MYRIAD strategic award "Promoting Mental Health and Building Resilience in Adolescence: Investigating Mindfulness and Attentional Control"; they are acknowledged as group authors in this article for their substantial contributions to the project development, in accordance with the MYRIAD dissemination protocol.

Kirsty Griffiths played a lead role in formal analysis, project administration, writing–original draft, and writing–review and editing. Darren L. Dunning curated and investigated the data for the study and reviewed the manuscript. Jenna Parker curated and investigated the data for the study and reviewed the manuscript. Marc Bennett curated and investigated the data for the study and reviewed the manuscript. Susanne Schweizer curated and investigated the data for the study and reviewed the manuscript. Lucy Foulkes curated and investigated the data for the study and reviewed the manuscript. Saz Ahmed curated and investigated the data for the study and reviewed the manuscript. Jovita T. Leung curated and investigated the data for the study and reviewed the manuscript. Cait Griffin curated and investigated the data for the study and reviewed the manuscript. Ashok Sakhardande curated and investigated the data for the study and reviewed the manuscript. Willem Kuyken conceptualized the study. J. Mark G. Williams conceptualized the study. Sarah-Jayne Blakemore conceptualized the study. Tim Dalgleish conceptualized the study and played a lead role in writing and reviewing the manuscript. Jason Stretton played a lead role in writing–review and editing, and an equal role in formal analysis and writing–original draft.

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scenes, relative to neutral. Performance in each condition and the performance "cost" for completing the task in negative relative to neutral conditions was not modulated by depressive symptoms. Furthermore, age did not predict performance cost, irrespective of depressive symptoms. These findings suggest that WM capacity is relatively robust against socioaffective contexts and mood in adolescents.

Keywords: affective control, working memory, depression, adolescence

Supplemental materials: https://doi.org/10.1037/emo0001390.supp

People exhibit marked individual variation in their ability to exercise cognitive control in affectively charged situations. This "affective control," the ability to maintain focus on important goals when generating and acting on behavioral plans in affective contexts, is a signature of success in occupational and educational contexts and in maintaining good mental health and well-being (Gray, 2004). Moreover, a diminished capacity for affective control is associated with a broad spectrum of psychiatric conditions—such as depression (Schweizer et al., 2019). This capacity is typically assessed in laboratory settings by comparing performance on carefully constructed executive control and working memory (WM) tasks performed in both affectively neutral ("cool") and affectively charged ("hot") contexts (Schweizer, Gotlib, & Blakemore, 2020). The relative performance "cost" of completing the task in hot contexts thus provides an assay of how much cognitive control is compromised by affective contexts.

Adolescence (aged 10–24 years) is a period when executive functioning generally undergoes significant change (Luna, 2009; Sawyer et al., 2018). Relatedly, adolescence is also a hypersensitive period for sociocognitive processing, whereby adolescents must quickly learn to navigate through complex peer-group dynamics within their social environment (Blakemore, 2019; Blakemore & Mills, 2014; Crone & Dahl, 2012). Furthermore, adolescence is characterized by profound emotional development (Blakemore & Mills, 2014; Cohen et al., 2016; Crone & Dahl, 2012) alongside an associated increased risk of depression (Brière et al., 2013; Holmes et al., 2016; Kessler et al., 2005), which often has its initial onset during the adolescent years. Critically, there is some consensus that the maturation of executive functioning is slower than the development of emotional functioning (Ernst et al., 2006; Shulman et al., 2016) and that this developmental misalignment might be a significant contributing factor to the risk of developing depression (Schweizer, Gotlib, & Blakemore, 2020; Schweizer et al., 2019). For these reasons it is important to understand how a multifaceted process such as affective control interacts with vulnerability to depression.

Affective control is thought to significantly improve through adolescence (for a review see Schweizer, Gotlib, & Blakemore, 2020). Performance on the affective go/no-go task (Cohen et al., 2016), and the emotional Stroop task (Lagattuta et al., 2011) has shown a linear age-related reduction in interference from task-irrelevant negative emotive stimuli that requires response inhibition. Furthermore, performance on an *n*-back task revealed that adolescent (12–14 years) affective control is compromised relative to late adolescents and young adults (18–29 years) only when the positive affective material is task irrelevant, with no difference between adolescents and adults when the affective material is directly relevant to the task procedures (Cromheeke & Mueller, 2016). A similar finding was also reported in adolescents (12–16) relative to adults (25–35) in a study using happy and angry faces as the affective stimuli (Mueller et al., 2017).

The relationship between affective control and depression is relatively consistent, with poor affective control being associated with the presence of depression in adolescents (Kilford et al., 2015; Ladouceur et al., 2013; Mirabolfathi et al., 2022). However, less is known about age-related or developmental changes in the relationship between depression and affective control (Schweizer, Gotlib, & Blakemore, 2020) in adolescence. One study that has examined this question reported that depression was associated with poorer affective control as a function of age, with younger adolescents (11–14 years) showing a stronger interaction relative to their older peers (15–18 years) and to young adults (22–30 years), despite showing relatively superior affective control in general (Schweizer, Parker, et al., 2020). This however is a single study that focused on set-shifting ability under affective conditions. To our knowledge there has been no assessment of affective control assayed via working memory capacity (WMC) paradigms in adolescents.

Relatedly, a large-scale meta-analysis showed small but reliable deleterious effects in WM performance in adults when the distracting information was negatively affectively laden, with memory recall worse in negative compared with neutral contexts (Schweizer et al., 2019). Importantly, 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 negative affective material relative to healthy adults. This suggests that WM performance on tasks including negatively affective compared with neutral information may be a sensitive marker of mental health status. However, the relationship to mental health problems is complex; affective WM appears to be reduced in some studies in individuals with dysphoria (Hubbard, Hutchison, Hambrick, & Rypma, 2016; Hubbard, Hutchison, Turner, et al., 2016), posttraumatic stress disorder (Schweizer & Dalgleish, 2016), and depression (Joormann & Gotlib, 2008; Kertz et al., 2016), while other studies suggest that affective WM performance is maintained across variations in mood (Tavitian et al., 2014; Yoon et al., 2014). Whether similar relationships between affective WM capacity and poorer mental health exists in adolescents is unknown.

This study therefore investigated the relationship between affective control (assayed as affective WM capacity) and symptoms of depression in typically developing adolescents. For the present study, we adapted the Affective Picture Span Paradigm (APSP; Schweizer & Dalgleish, 2016) with affectively laden social stimuli as task-irrelevant distractors. In the APSP, the participant's task is to remember sets of neutral words presented one after the other while also having to count the number of neutral shapes superimposed on the background affective or neutral images. Socially stressful scenes (e.g., social exclusion, bullying) were chosen as negative affective stimuli with neutral social stimuli (e.g., people sitting on a bus) chosen as the control condition. Previous work has shown that these stimuli reliably disrupt executive functioning (Fuhrmann et al., 2019) with social stressors experienced during adolescence being particularly detrimental to mental health (Fuhrmann et al., 2015). Given that peer victimization and bullying are relatively common experiences in childhood and adolescence, with approximately 30% of U.K. secondary school head teachers reporting weekly bullying incidents (Organisation for Economic Co-operation and Development, 2018; https://web-archive.oecd.org/temp/2024-04-10/523891-talis2018tables.htm), our rationale was that these real-world scenarios would have high relevance to our adolescent sample. Poorer affective WM is indexed as a greater reduction in memory performance in the affective (negative) condition, when the images are socially stressful scenes, than in the neutral condition.

To examine relationships to depression symptoms, we used scores on a widely used self-report measure of depression, the Center for Epidemiological Studies–Depression Scale (CES-D; Radloff, 1977), in a large unselected sample of adolescents.

Our hypotheses were as follows:

> *Hypothesis 1*: There will be a WM performance cost for all adolescents, with performance in the negative condition significantly lower than in the neutral condition.
>
> *Hypothesis 2*: The performance cost will be greater for younger adolescents relative to older adolescents.
>
> *Hypothesis 3*: Adolescents with higher depressive symptomatology will show a greater performance cost relative to those with lower symptomatology.
>
> *Hypothesis 4*: This performance cost for adolescents with higher depressive symptomatology will decrease with age.

Method

Transparency and Openness

We report how we determined our sample size, all data exclusions, all manipulations, and all measures in the study. All analysis code, data, and research materials are publicly available on Open Science Framework and can be accessed at https://osf.io/xubyr/ (Stretton, 2023). Data were analyzed using SPSS, Version 28 (IBM) and R (Version 4.2.2). This study's design and its analysis were not preregistered. For the purpose of open access, the author has applied a Creative Commons Attribution (CC BY) license to any author accepted manuscript version arising from this submission.

Participants

A sample of 568 participants (aged 11–18 years) were recruited from 14 schools and two colleges in Greater London and Cambridgeshire, United Kingdom, between 2016 and 2018. Participants were recruited as part of a study examining the effectiveness, cost-effectiveness, mechanisms, scalability, and implementation of mindfulness (the "My Resilience in Adolescence" [MYRIAD] project, Theme 1B; https://osf.io/d6y9q/).

The MYRIAD project was advertised to local secondary schools and colleges, with participants recruited through teachers, school letters, and assemblies (students aged 11–18 years). Participants were offered the opportunity to take part unless (a) they had a self-reported diagnosis of a neurodevelopmental or neurological disorder, or they had learning difficulties, and/or (b) they had a self-reported history of a mood disorder. In total, data from 425 participants (range = 11.50–18.5 years; $M = 14.42$, $SD = 1.73$) were available for full analysis (see Table 1 and Supplemental Figure S1 for age distribution). A total of 143 participants were removed from the main analysis either because they did not complete both conditions of the affective WM task ($n = 24$), or they were inadvertently allocated an incorrect version of the counterbalanced task ($n = 44$), or the task failed during testing ($n = 22$), or they had a special educational need requirement that was not initially reported ($n = 1$), or they failed to meet the attention target detection rate (ATDR) threshold for the WMC task ($n = 37$). In addition, 15 participants' demographic information were missing including age ($n = 2$), IQ ($n = 7$), gender ($n = 1$), and self-reported mood ($n = 5$). A sensitivity power analysis (G*Power, 3.1.9.2) with a sample of $n = 425$, $\alpha = .05$, and 80% power (see Supplemental Materials for MYRIAD power analysis) revealed a minimum detectable effect size ($d = 0.13$) for a paired t test (Hypothesis 1). For Hypotheses 2–4, the linear mixed-effects models, with a sensitivity power analysis for the χ^2 goodness of fit with the same parameters (with 12 degrees of freedom), revealed a minimum detectable effect size of $w = 0.18$ when comparing the full versus restricted models.

The study was approved by the Cambridge University Psychology Research Ethics Committee and University College London Research Ethics Committee. Informed consent from parents and assent from participants were obtained for participants under 16 years old, and informed consent was obtained for participants over 16 years old. Participants were compensated £15 in vouchers for taking part.

Table 1
Participant Characteristics of the Analyzed Sample

Characteristic	*n* (%)/*M* (*SD*)
Sociodemographic	
Age, years; *M* (*SD*)	14.42 (1.73)
Gender, *n* (%)	
Female	284 (66.8)
Male	141 (33.2)
Mental health	
Depression, CES-D; *M* (*SD*)	17.44 (10.77)
Lower risk, *n* (%)	221 (52.0)
At risk, *n* (%)	204 (48.0)

Note. $n = 425$. Cell size (n) and percentages (%) are given for categorical variables and means and standard deviations (SD) for continuous variables. CES-D = Center for Epidemiological Studies–Depression Scale.

Measures and Materials

Mood Measure

Center for Epidemiological Studies–Depression Scale (CES-D; Radloff, 1977). The CES-D is a 20-item self-report questionnaire in which participants were asked about feelings or behaviors 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 can range from 0 to 60 (current sample range: 0–56) with higher scores indicative of greater depression symptomatology (see Supplemental Table S7 for

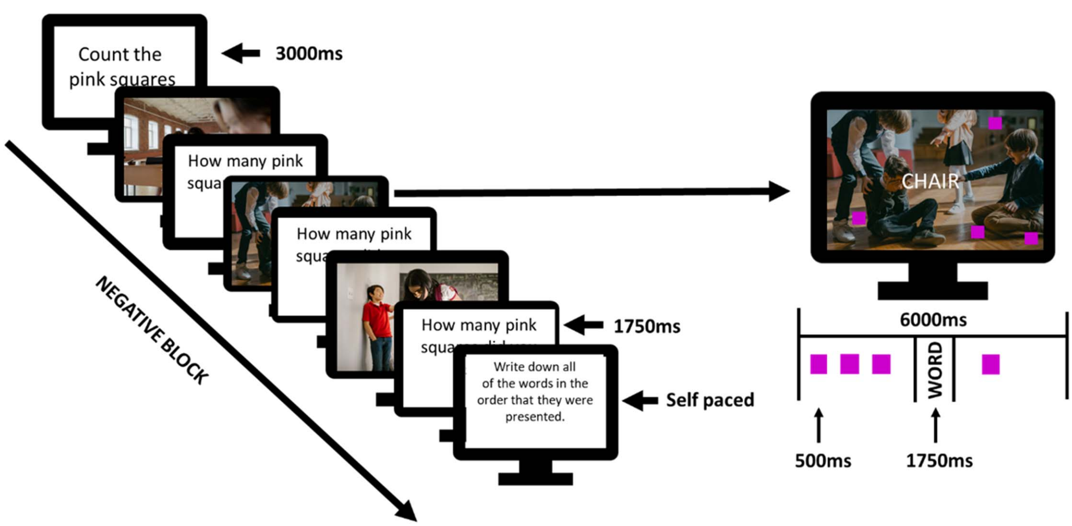
distribution statistics). The CES-D provides cutoff scores for those deemed
to be "at risk" (CES-D ≥ 16) and "lower risk" (CES-D < 16) of depression, with good sensitivity and specificity and high internal consistency (Lewinsohn et al., 1997), and this cutoff was used for supplementary analyses. For CES-D questionnaires that contained <20% missing items, values were replaced by the individual scale mean (Enders, 2010). When >20% of items were missing ($n = 5$), participants were removed from the final analysis.

The Affective Picture Span Paradigm. The APSP was an adapted version of a task previously used in adults (Schweizer & Dalgleish, 2016). The task comprised two cognitively engaging components. The first is a target (storage) task, where participants are explicitly told to read, learn, and retain a set of words, presented one word per trial in blocks of two to five trials and superimposed upon a background image (see Supplemental Table S1 for the list of words used). The second component is the operation (distractor) task, which was interpolated with the target task, and appeared over the same background image on each trial. The operation task was the presentation of a pink square, which appeared one at a time and sporadically over the background image (see Figure 1). The pink square appeared between 3 and 6 times per trial, with the average comprising five squares per trial. Participants were instructed to count and report the number of shapes within a given trial while at the same time being told to memorize the target cue word on that trial.

Over the course of each trial (6000 ms), participants first saw a series of pink squares that appeared one at a time and sporadically over the background image. The shape that appeared for 500 ms at varying time intervals, ranging between three and six shapes per trial. After the operation component, the target cue word was presented in the center of the screen (1750 ms), which was then followed by a new blank screen that indicated to the end of the trial presentation. Participants were then prompted with the operation task (i.e., input the number of shapes they had seen in that trial, seen using the numerical keys on the keyboard). A response had to be provided within 1750 ms before the next trial started or the block ended. Trial blocks comprised between two and five trials. At the end of a trial block, participants were asked to type as many of the presented words (ranging between two and five words) as they could remember and in the order in which they had been presented. There was no time restriction on the target word recall. The recall screen presented one blank box per word to cue participants on how many words had been presented.

Task valence was manipulated by presenting socially relevant background images that were either affectively neutral (APSP-neutral condition) or affectively 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 (a) emotional arousal and (b) negative valence. Significant differences in valence and arousal were found between

Figure 1
A Sample Four-Trial Block for the Affective Picture Span Paradigm (APSP) for the APSP-Negative Condition



Note. Briefly, the task comprises two cognitively engaging components. The first is a target (storage) task, where participants are told to learn and retain a set of words superimposed upon a background image. The second component is the operation (distractor) task. Participants were instructed to count the number of shapes overlaid on the background image within a given trial while at the same time being told to memorize the target cue word on that trial. All images are copyright- and royalty-free and taken from https://www.pexels.com/. The license information for these images is https://www.pexels.com/license/. The individual image addresses (from the top left in the figure) are as follows: Picture 1 (https://images.pexels.com/photos/7396509/pexels-photo-7396509.jpeg?auto=compress&cs=tinysrgb&w=1260&h=750&dpr=2), Picture 2 (https://images.pexels.com/photos/7929446/pexels-photo-7929446.jpeg?auto=compress&cs=tinysrgb&w=1260&h=750&dpr=2), and Picture 3 (https://images.pexels.com/photos/6936338/pexels-photo-6936338.jpeg?auto=compress&cs=tinysrgb&w=1260&h=750&dpr=2). Adapted from "The Impact of Affective Contexts on Working Memory Capacity in Healthy Populations and in Individuals With PTSD," by S. Schweizer and T. Dalgleish, 2016, *Emotion*, *16*(1), pp. 16–23 (https://doi.org/10.1037/emo0000072). Copyright 2016 by the American Psychological Association. See the online article for the color version of this figure.

the affectively neutral and negative backgrounds (see Supplemental Table S2).

For each condition, participants went through two sets of four blocks of differing, randomized, and counterbalanced cognitive load (two, three, four, and five words), totaling 28 trials over 8 blocks. The order of conditions was also counterbalanced, with half of the testing group allocated the APSP-neutral or APSP-negative condition first. After completing the first set of eight blocks, participants had a brief break before they continued with the second condition. The whole task took approximately 15 mins to complete 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.

To reduce floor effects in this younger population, adjustments were made to the adult version of the APSP, as follows: (a) reducing the maximum block size from seven trials to five trials, (b) using only one type of target shape at a time for the operation component, (c) adding slots to the recall screen matching the number of words presented, (d) reducing the proportion of operation task trials that needed to be correct for the participant's data to be retained (the ATDR) to 42.75% (see Supplemental Methods for further details), and (e) extending cue screen time, with shape presentation increasing 250–500 ms and the cue word increasing from 350 to 1750 ms.

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 order of presentation (Conway et al., 2005), summed across the eight blocks in each condition (results for reliability and the effects of cognitive load can be found in the Supplemental Materials).

Data Analysis

All statistical analyses were conducted in SPSS (v.28 IBM) and R (Version 4.2.2).

Linear mixed-effects models were used to assess all hypotheses. We specified a full model using maximum likelihood estimation with APSP score entered as the dependent variable and valence (negative and neutral) and gender as fixed effects, age and CES-D scores as covariates, subject as a random intercept, and cognitive load (2-, 3-, 4-, and 5-item load) as a repeated random factor. We additionally included the interaction terms for Age × Valence (Hypothesis 2), Age × CES-D (Hypothesis 3), and Age × CES-D × Valence (Hypothesis 4) as predictors. In a planned comparison, we used the estimated marginal means of Valence to test for main effects of Valence (Bonferroni corrected; $p < .05$) adjusted for all variables in the model (Hypothesis 1). We next specified a restricted model excluding the CES-D score (and its interaction terms) to assess the effects of depressive symptomatology on APSP score. Likelihood ratio tests were used to compare the χ^2 distribution, using the −2 log likelihood (LL) (significance level $p < .05$) between the full and restricted models. The likelihood ratio test was calculated using the difference between the −2LL and degrees of freedom (DF) in the full and restricted models (restricted–full), and one-sided p value was determined using the *pchisq* function in R and the following formula (Equation 1):

$$1 - \mathrm{pchisq}(\chi^2\mathrm{difference}, \mathrm{DF\ difference}). \quad (1)$$

To test for the effects of depressive risk group (low vs. high), we repeated these analyses replacing the continuous variable of CESD score with the binary risk group variable. For completeness, we also ran the same analyses using the ATDR score (see Supplemental Results for risk and ATDR analyses).

Effect sizes were calculated for planned comparisons in the full models where appropriate (Cohen's d) and for the χ^2 distribution in likelihood ratio tests for model comparisons (Cohen's w). Cohen's w was calculated as $\sqrt{\chi^2/N}$. Where <20% participant data were missing on a subset of items, the average scores across the nonmissing items were calculated and included; otherwise, the total score was noted as missing (Enders, 2010).

Procedure

The majority of testing took place in groups of 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 Medical Research Council Cognition and Brain Sciences Unit. Testing sessions were 3 hr long and, due to testing constraints, were split over two sessions. For each session, laptops were spread out across the room to minimize distraction and to maintain confidentiality. The present study was part of a larger battery of tests during the baseline session for a study investigating the mechanisms of mindfulness.

Results

Participant Characteristics

Descriptive data for the sample are described in Table 1.

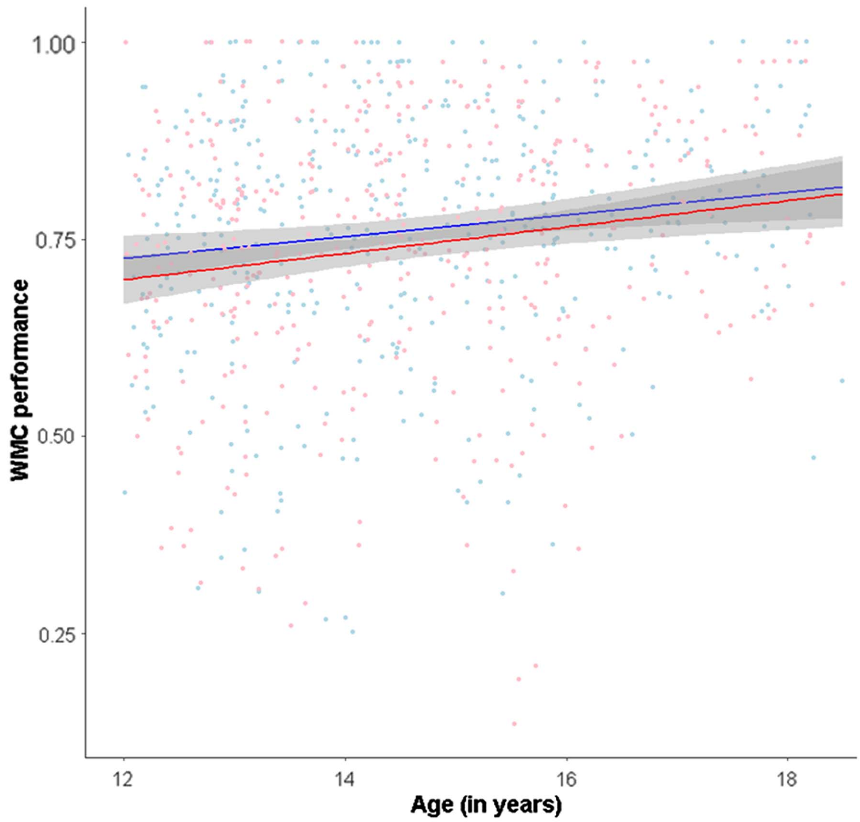
Zero-order correlations across the overall sample indicated significant associations between age, gender, and CES-D (see Supplemental Table S4). These variables were included as factors or covariates, as relevant.

Linear Mixed-Effects Model for Predicting Affective Picture Span Paradigm Performance

Full Model

In line with our first hypothesis, a planned comparison revealed a significant difference in performance between the APSP-neutral and APSP-negative conditions across all participants, $F(1, 2769.6) = 7.6$, $p = .006$, $d = 0.13$, with participants recalling a higher proportion of words in the APSP-neutral ($M = .78$, $SE = .01$) condition relative to the APSP-negative ($M = .76$, $SE = .01$) condition. The full model, −2 LL(df) = 139.11(12), revealed a significant main effect of age on APSP performance ($\beta = 0.18$, $t = 2.34$, $p = .018$, CI [.003, .033]) indicating that performance in both conditions improved with older age (Figure 2, Table 2). Older participants performed better in word recall across both conditions relative to younger participants (APSP-neutral: $t = 3.14$, $\beta = 0.15$, $p = .002$; APSP-negative: $t = 4.02$, $\beta = 0.19$, $p < .001$). However, there was no significant Age × Valence interaction ($\beta = -.08$, $t = -1.23$, $p = .22$, CI [−.21, .05]), failing to support the second hypothesis (i.e., the performance cost would be greater for younger adolescents relative to their older peers). Similarly, there was no significant effect of the CESD score ($\beta = 0.003$, $t = .74$, $p = .46$, CI [−.006, .013]) nor the Age × CESD interaction ($\beta = -.002$,

Figure 2
Individual Plots, Adjusted for Covariates, for Working Memory Capacity Neutral (Blue) and Negative (Red) Conditions, With Age Error Bands Are ±1 Standard Error of the Mean



Note. WMC = working memory capacity. See the online article for the color version of this figure.

$t = -.78$, $p = .44$, CI [−.0001, .0004]) contrary to our third hypothesis. Finally, the CES-D × Age × Valence interaction was not significant ($\beta = -1.97$, $t = -.39$, $p = .696$, CI [−.0001, 7.99]) failing to support Hypothesis 4 that performance cost would decrease with age in those with higher depressive symptomatology.

Restricted Model

In the restricted model, −2 LL(*df*) = 140.21(9) (excluding CESD and its interactions), age again was the only significant predictor of APSP performance ($\beta = 0.13$, $t = 2.96$, $p = .003$, CI [.004, .022]; Table 3). Corroboratively, the likelihood ratio test of the χ^2 distribution of the two models was not significant ($p = .77$, Cohen's $w = 0.05$) indicating that the addition of CESD and its interactions were not significant in predicting performance on the APSP. The same pattern of results was found for ATDR performance (see Supplemental Results).

Taken together, these findings indicate that, when depressive symptoms were analyzed as a continuous measure (CES-D), there were no reported changes in APSP performance in each condition with varying depressive states. In addition, APSP performance was the same, irrespective of whether younger or older adolescents had greater depressive symptoms. These effects held when analyzing the CES-D using a risk cutoff score (<16>) (see Supplemental Results, Supplemental Table S5 and S6).

Discussion

This study investigated the effects of affective contexts on WMC during adolescence and whether those effects were moderated by depression symptoms. We used a computer-based task to assess WMC that required participants to remember and recall a list of the target cue words while ignoring affective task-irrelevant background images. The aims were to establish whether there was a performance cost of affective condition, whether there were any age-related changes in WMC, and whether any performance cost was altered by age or depressive symptoms or their interaction.

In line with our first hypothesis, the negative background images (relative to neutral) impaired WMC performance. This finding is consistent with a similar APSP paradigm (Schweizer & Dalgleish, 2016), with participants showing a small decrement in WM storage and retrieval in negative compared with neutral contexts. This demonstrates that adolescents have a relative difficulty in maintaining affective control against a backdrop of socioaffective stimuli. This could be due to the additional cognitive resources required to ignore negative stimuli relative to neutral stimuli (Gibb et al., 2016) or to the attention-grabbing properties of negative stimuli that shift the

Table 2
Full Linear Mixed-Effects Model Including Age, Valence, Total Center for Epidemiological Studies–Depression Scale Scores, and Interactions for Predicting Affective Picture Span Paradigm Performance

Effect	Estimate	*SE*	*df*	95% CI *LL*	95% CI *UL*	*p*
Fixed effects						
Intercept	.5209	.1106	489.9	.31	.74	<.001
Age	.0183	.0007	496.6	.01	.03	.018*
Valence	−.0818	.0667	2769.6	−.21	.04	.22
CES-D	.0003	.0049	405.6	−.00	.01	.46
Valence × Age	.0045	.0048	2769.6	−.00	.01	.35
CES-D × Age	−.0002	.0003	410.1	−.00	.00	.44
CES-D × Age × Valence	−.0000	5.0393	2769.6	−.00	.00	.69
Random effects						
Subject	.0123	.0013	N/A	.01	.015	<.001
Repeated effects						
Load 2	.046	.0028	N/A	.04	.05	<.001
Load 3	.043	.0023	N/A	.038	.047	<.001
Load 4	.0504	.0028	N/A	.045	.05	<.001
Load 5	.0812	.0046	N/A	.072	.09	<.001

Note. *n* = *425*. CES-D was included as a continuous variable. *SE* = standard error; *df* = degrees of freedom; CI = confidence interval; *LL* = lower limit; *UL* = upper limit; CES-D = Center for Epidemiological Studies–Depression Scale; NA = not applicable.
* $p < .05$.

attentional resources away from the central task demand of remembering the target words (Pratto & John, 1991). The effect in the present study was small (Cohen's $d = .13$); however, this is consistent with previous findings in this area (Funder & Ozer, 2019). Considering how frequently we use affective control, even small effects such as the ones reported here are likely to have an impact on everyday cognition in adolescents (Schweizer et al., 2019).

We also report an overall positive linear relationship between WMC (for both negative and neutral conditions) and age. The age-related variance between younger and older adolescents may reflect age-related differential cognitive processing, such as the enhanced ability to inhibit task-irrelevant distractors for a task-relevant response, central to cognitive control (Luna, 2009; Schweizer, Gotlib, & Blakemore, 2020). Indeed, this protracted development in cognition mirrors the structural maturation of the frontoparietal regions (Blakemore & Mills, 2014; Darki & Klingberg, 2015; Tamnes et al., 2010), which are central to executive aspects of WMC. It is possible that younger adolescents—with relatively immature executive functions—may struggle to attend to task-relevant goals in the face of task-irrelevant distractors (whether these are affectively charged or not).

There was no significant age-related variance in the *affective* performance cost. This finding contrasts with previous studies showing age-related reduction in interference from affective stimuli on task performance (see Schweizer, Gotlib, & Blakemore, 2020, for a review). Instead, the findings here suggest that the affective control systems for regulating negative (hot) and neutral (cool) everyday tasks are age invariant in adolescence. Similarly, we found no significant interactions with valence and depression symptomatology or depressive risk status, nor did we report a decrease in the performance costs among older adolescents with greater symptoms or in the at-risk group, with effect sizes in model comparisons (all Cohen's $w \leq 0.05$). Caution is always warranted when interpreting nonsignificant findings despite the effect size being trivial in magnitude. However, these results suggest that any compromises in affective control cannot be reliably attributed to the mental health status of the adolescents in this study. This is in contrast with much of the previous literature (Kilford et al., 2015; Ladouceur et al., 2013; Mirabolfathi et al., 2022). We suggest that this may reflect differences in methodology for assaying affective control under the umbrella of "WM tasks" in general. For example, previous studies have focused solely on set-shifting ability (Schweizer, Parker, et al., 2020). This study is the first to assay affective control in adolescents

Table 3
Restricted Linear Mixed-Effects Model Including Age, Valence, and Interactions for Predicting Affective Picture Span Paradigm Performance

Effect	Estimate	*SE*	*df*	95% CI *LL*	95% CI *UL*	*p*
Fixed effects						
Intercept	.59	.65	718.3	.46	.72	<.001
Age	.01	.01	718.3	.01	.02	.003*
Valence	−.07	.06	2769.3	−.21	.51	.24
Valence × Age	.01	.01	2769.3	−.01	.01	.393
Random effects						
Subject	.0123	.0013	N/A	.01	.015	<.001
Repeated effects						
Load 2	.046	.0028	N/A	.04	.05	<.001
Load 3	.043	.0023	N/A	.038	.047	<.001
Load 4	.0504	.0028	N/A	.045	.05	<.001
Load 5	.0812	.0046	N/A	.072	.09	<.001

Note. *n* = *425*. *SE* = standard error; *df* = degrees of freedom; CI = confidence interval; *LL* = lower limit; *UL* = upper limit; NA = not applicable.
* $p < .05$.

using a dual-task WM capacity paradigm, and although we find no evidence for deleterious effects of depressive symptomatology or risk status on performance, this pattern of results is similar to that reported in adult studies with depression, which also show little support for the differential effects of affective material on WM (Joormann & Gotlib, 2008; Ladouceur et al., 2013; Tavitian et al., 2014; Yoon et al., 2014).

One factor that might have contributed to these results is our choice of affectively charged stimuli in this study. We included scenes of social exclusion and bullying, in contrast to stimuli used in a previous APSP paradigm that depicted more saliently emotive real-world scenarios (e.g., burn victims, street violence, animals under surgery). This was because we reasoned that scenes of social jeopardy would have more affective salience for an adolescent sample. One possibility is that, although the stimuli used in this study were independently rated as affectively significant in terms of valence and arousal, it is possible that they were not sufficiently salient to impact the cognitive control resources in adolescents considered at risk for depression and using a categorically different stimulus set (i.e., physical harm vs. socioemotional harm) could have contributed to the differences observed (see Schweizer et al., 2019, for a discussion). Relatedly, it has been suggested that habitual use of complex emotion regulation strategies emerges as a function of improved cognitive control (Aldao et al., 2015) and that habitual use increases linearly from late childhood to early adulthood (Zimmermann & Iwanski, 2014). An alternative possibility therefore is that, as bullying in the form of social exclusion is experienced more frequently than physical harm in U.K. adolescents (Department of Education, 2018; https://www.gov.uk/government/publications/longitudinal-study-of-young-people-in-england-cohort-2-wave-2), the habitual use of cognitive control and emotional regulation strategies related to tackling these issues is already well-rehearsed and effective in controlled experimental conditions, regardless of age and symptom status.

This study has some limitations. Data collection was done in small groups after school with some students neighbored next to peers. Peer presence has been shown to impact adolescents' relational reasoning and decision making compared with other age groups, indicating that environmental factors could impact task performance (Chein et al., 2011; Wolf et al., 2015). While the present study sought to minimize distraction during testing (e.g., exam-style conditions), the attention spans in this study were lower than expected relative to previous complex span tasks (Conway et al., 2005). Second, we did not collect valence and arousal ratings for the affective images from participants (instead relying on preratings from a similar sample). Finally, as previously discussed, the use of categorically different stimuli (physical harm vs. socioemotional harm) relative to previous versions of the task may have contributed to differences in salience despite the independent valence and arousal ratings obtained from an independent sample.

In summary, we adapted the APSP to investigate whether affective control was compromised in an adolescent sample. Overall, WMC was poorer when the background distractors were affectively negative relative to neutral. WMC (in both negative and neutral conditions) increased as a function of age; however, there were no age-related changes in the degree of performance decrement in negative contexts (vs. neutral) over development. We also found that performance was not significantly influenced by depression symptomatology, nor do we report age-related changes in the relationship between mental health risk and putative affective control difficulties. These findings suggest that the impact of affectively negative information on WMC is relatively robust to individual differences in age and mental health status in adolescence.

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