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Emotional devaluation in ignoring and forgetting as a function of adolescent development.

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Abstract

We know that emotion and cognition interact to guide goal-directed behaviour. Accordingly, it has recently been shown that distracting stimuli (Raymond et al., 2003) and instructed to-be-forgotten items (Vivas et al., 2016) are emotionally devaluated. The *devaluation by inhibition hypothesis* (Raymond et al., 2003) is the main theoretical explanation of these effects. However, we know little about how the cognition-emotion interplay is further modulated by development, and particularly, by changes in inhibitory control and affective processing within the adolescence period. In the present study we combined a selective attention task with faces, and a selective memory (directed forgetting paradigm) task with words, with a pleasantness evaluation task to address this question in three age groups; younger adolescents, older adolescents and young adults. Younger adolescents exhibited worse accuracy in the attention task, lower overall recognition of words in the memory task, and a smaller in magnitude directed forgetting effect in the latter, relative to the two older groups. That is, they showed less efficient inhibitory control in attention and memory selection. Despite this, all groups showed similar devaluation effects of the distractor faces and the to-be-forgotten words. Our findings do not fully support an inhibition account of such effects. Yet, they support the robustness of the *forgetting devaluation effect*, replicating the findings of Vivas et al. (2016) with a Greek version of the task and in a bigger sample of participants.

Key words: directed forgetting; attention selection; emotional devaluation; adolescence

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In order to successfully achieve goal-directed behaviour we need to select within a crowded environment what is important, while successfully resisting interference from irrelevant but salient stimuli (e.g., a pop-up add while reading a web page). Research in the field of attention has proposed that inhibition of unwanted information may guide goal-directed behaviour by decreasing the perceptual saliency of task-irrelevant information, and consequently, increasing the ratio of signal over noise (Desimone, 1998). In the field of memory, similar selective mechanisms may be responsible for “motivated forgetting” (see Anderson & Hanslmayr, 2014, for a review). That is, inhibition of unwanted intrusive information (Anderson & Spellman, 1995; Anderson & Green, 2001; Bjork, 1970; but see Sahakyan & Kelley, 2002, for a non-inhibitory explanation) may underlie typical memory effects in paradigms such as *Think-No Think* (Anderson & Green, 2001; Anderson & Levy, 2009) or *Directed Forgetting*, where recognition accuracy is worse for stimuli that were previously instructed to be forgotten relative to those that were instructed to be remembered (Bjork, 1989; Fawcett & Taylor, 2008; Ludowig et al., 2010). Accordingly, ignoring and forgetting might share mechanisms and resources that are necessary to prevent outdated, irrelevant, or undesirable information from interfering with memory encoding and retrieval, as well as with selection-for-action of goal-relevant information.

Raymond et al. (2003) proposed that the emotion system may additionally guide goal-directed behavior, by decreasing the emotional value, and consequently, the neural signal of the task-irrelevant information. Specifically, they found that stimuli that were distractors in a previous attention-localization task were subsequently rated drearier than the preceding targets and novel stimuli. In a second experiment, Raymond and colleagues reported emotional devaluation of stimuli that were of the same category with a previous distractor stimulus. Thus, ignoring appears to have negative effects on emotional ratings for both distractors and novel stimuli that share similar features.

Raymond and colleagues (2003) proposed the *devaluation by inhibition hypothesis* as a theoretical explanation for the lower distractor evaluation ratings. Based on this hypothesis, emotional devaluation would be similar to the reduced saliency of irrelevant stimuli associated with active inhibition in selective attention (Moran & Desimone, 1985). In line with Kessler and Tipper's (2004) explanation of inhibition as a *tag* associated with the distractor's representation, the authors proposed that such labelling renders a stimulus less emotionally valuable when re-encountered, so as to hinder re-capturing of attention.

Several studies have supported the inhibitory account of the *distractor devaluation effect* in adults; studies demonstrating the effect as a function of object-based (Raymond et al., 2003), feature-based (Goolsby, Shapiro, & Raymond, 2009; Goolsby, Shapiro, Silver, et al., 2009; Raymond et al., 2003), location-based (Raymond et al., 2005), semantic (Zhou et al., 2007) or motor inhibition (Fenske et al., 2005; Kiss et al., 2008). Furthermore, the amplitude of the N2pc component, which is thought to reflect attention to the target and suppression of the distractor stimulus, has been associated with the distractor devaluation effect (Kiss et al., 2007, 2008). Goolsby, Shapiro, and Raymond (2009) also showed that the devaluation effect was eliminated under a high working memory load condition, which was proposed to interfere with successful inhibition of distracting information.

We further suggested (Vivas et al., 2016) that the emotion system may, in a similar way, guide intentional forgetting of unwanted information. That is, combining a directed forgetting paradigm with an emotional evaluation task, we found that to-be-forgotten items were emotionally devaluated as compared to items that were instructed to-be-remembered. We proposed that as with selective attention, the emotional devaluation of intentionally forgotten items may be adaptive, so that these items are less available for later retrieval. In a recent study, De Vito and Fenkse (2017) extended this finding using a *Think/No-think* paradigm: they reported emotional devaluation of objects and words for which retrieval from long-term memory was suppressed (*No-think* instruction), relative to baseline items (not associated with retrieval instruction). Yet, a third earlier study, using a *retrieval-induced forgetting* paradigm, failed to find emotional devaluation of unpracticed (forgotten) items from practiced categories, relative to desired practiced items (Janczyk & Wühr, 2012). However, as we noted (Vivas et al., 2016; see also De Vito & Fenkse, 2017 for a discussion) there are key differences between the paradigms employed in these studies. Forgetting is intentional in the *Directed forgetting* and *Think/No-think* paradigms, involving active suppression of encoding and retrieval, respectively, of unwanted explicit information. This is not the case though for the paradigm used by Janczyk and Wühr, where forgetting is an incidental effect of selective retrieval.

It should be noted here that an alternative account, not based on inhibition, has been put forward to explain the distractor devaluation effect. According to Dittrich and Klauer's (2012) *evaluative coding hypothesis,* categorizing a stimulus as a distractor, a non-response or a to-be-forgotten (TBF) item, activates a context-dependant negative affect encoding. From this view, the devaluation effect would result from general affective response biases associated to the experimental instructions. However, when testing this hypothesis with adults (Vivas et al., 2016), we found that the emotional devaluation of intentionally forgotten words was not affected by the induction of a positive affect state associated with the *forget* instruction.

In the present study, we propose that adolescence may be an interesting and informative period to study the effect of cognitive inhibition on affective evaluation (Baijal et al., 2011; Willoughby et al., 2012; see also Lightfoot et al., 2018). That is, developmental changes in cognitive processing during adolescence allow for testing of predictions regarding the mechanisms underlying devaluation effects. Specifically, research supports a gradual refinement of cognitive inhibition through adolescence (Best & Miller, 2010). For instance, using variations of the Stroop task, Huizinga et al. (2006) showed that resistance to interference continues to improve until the age of 15. Similarly, working memory, a construct closely related to attentional control and inhibition, shows linear improvement from 4 to 15 years of age (Gathercole et al., 2004). These findings are in agreement with studies supporting that the maturation of prefrontal regions, namely of brain areas that are greatly involved in such higher-order processes, continues in adolescence, extending into early adulthood (Conway & Fthenaki, 2003; Diamond, 2002; Hanslmayr et al., 2012). Adolescence is characterized by important changes in social and affective processing as well (see Steinberg, 2005). For example, Crone and Dalh (2012) concluded that affective processing, both positive (e.g., reward and perception of positive stimuli) and negative (e.g., perception of threat and aversive behavior) is found intensified in mid adolescence. Research also suggests that interactions between the affective and cognitive systems may modulate adolescents' performance and behavior. For instance, cognitive engagement in adolescents seems to be more flexible and to depend more strongly on motivational value (Crone & Dalh, 2012). However, research has so far focused on how emotional/affective input influences cognition. To our knowledge, no studies have investigated how cognition may modulate affective processing to guide goal-directed behavior within adolescence and in comparison to young adulthood.

Aiming for such an exploration, we employed a selective memory task (directed forgetting; Alonso & Diez, 2000; Vivas et al., 2016), and a selective attention task, both combined with an evaluation task, in younger adolescents, older adolescents, and young adults. Specifically, participants were required to suppress the encoding of words instructed to be forgotten in the memory task, and select (based on gender) a neutral face and report its age (*young* vs *old*), while ignoring a competing distractor face, in the attention task. Subsequently they rated words and faces, respectively, for pleasantness. We opted to employ tasks that have been typically used in the literature to measure selective attention and memory processes, and their effect on affective evaluation; yet, also considering task sensitivity to age-related differences. Specifically, directed forgetting paradigms typically employ words, and the particular version employed in this study has been shown to impose demands on executive functions which are under refinement during adolescence (i.e. working memory updating and inhibition; Aguirre et al., 2014; Best & Miller, 2010; Kliegl et al., 2017). On the other hand, visual search attention tasks typically employ visual stimuli (e.g, shapes or faces), and neutral faces have been employed to investigate distractor devaluation effects (see Vivas et al., 2016). The use of faces in our attention task was also expected to set greater demands for maintenance, and updating in working memory, making this task more sensitive to developmental changes (see Best & Miller, 2010).

With regard to the main aim of this study, we expected all groups to show emotional devaluation of the distractor (ignored) faces and the to-be-forgotten words. Moreover, if the devaluation-by-inhibition hypothesis holds, and given evidence of continuing refinement of attentional and memory inhibitory control within adolescence (especially its early phase; see Best & Miller, 2010), we expected modulation of devaluation effects by age group. That is, more efficient inhibition in young adults should result in greater in magnitude emotional devaluation effects.

We would like to emphasize that we employed two different cognitive tasks that have in common the involvement of controlled inhibitory processes; resistance to interference in the attention task and effortful active suppression of unwanted information in the memory task. If, as hypothesised above, all groups show devaluation effects in both tasks, this may be taken as further evidence in support, as well as generalization, of the devaluation-by-inhibition hypothesis. Such finding would also be in agreement with previous studies that have reported devaluation effects in tasks involving different inhibition types (e.g, semantic and motor; Zhou et al., 2007 and Fenske et al., 2005, respectively). As further hypothesized, any age differences observed in task performance should be primarily due to the development of inhibitory processes. If this is true, then any age-related modulation of the devaluation effects should not be task-specific.

Finally, based on Vivas et al. paradigm (2016), at the end of the memory task we included four questions to obtain self-report measures of the affect state (positive and negative) associated with the memory instruction (*remember* and *forget*). These additional self-report measures allowed us to test if any devaluation (of to-be-forgotten words) observed is modulated by the affective state associated with the memory instruction, as proposed by the evaluative coding hypothesis (Dittrich & Klauer, 2012).

Method

Participants

Participants in the initial sample were 87 adolescents and young adults (14 to 23 year-olds) recruited from state schools and university faculties in Northern Greece[1]. They were divided into three age groups: Younger adolescents (13-14 year olds; junior high-school students; 60% female; *N* = 26), Older adolescents (16-17 year olds; senior high-school students; 40% female; N=25), and Young adults (19-23 year olds; university students; 25% female; N=32). Four participants were excluded, since their age did not fall within the ranges above. The three age groups did not significantly differ on socio-economic status [$Mean_{Younger\ adolescents}$ = 7.08, SD = 1.75, $Mean_{Older\ adolescents}$ =7.16, SD = 1.70, $Mean_{Young\ adults}$=

[1] Power analysis (G* Power software, 3.1.9.2 version; Faul et al., 2009) revealed that 84 participants were enough for detecting a large effect size in the devaluation effect (η^2 = .14; power = .90; α= .05).

7.17, SD = 1.67; $F(2, 79) = .02$, $p = .977$, $\eta^2 = .001$], relying on measures of education level, occupation-type, and position in occupation that were provided by both participants' parents, as well as by young adults' themselves, in case they were already working (Ladas et al., 2015; Vivas et al., 2017, 2020). That is, 68% of the younger and the older adolescents, and 62.5% of the young adults were of lower socio-economic status (2-7 total score), whereas 32% of the younger and the older adolescents, and 37.5% of the young adults were of middle-class status (8-12 total score). The study was approved by the University of Sheffield Ethics Committee, and all adult participants, as well as the adolescents' parents provided written informed consent. Adolescents also gave informed assent to participate.

Measures

Both experimental tasks were created and ran with *E-Prime* (v2.1) software (Schneider et al., 2002).

The Memory-word task. The stimuli consisted of 216 words that were selected from a Greek standardized data base for emotional ratings using a SAM 9-point scale (Palogiannidi et al., 2016). All words selected had neutral ratings (between 4 and 6). Word frequency and length (syllables as well as phonemes contained) was then defined for all words, based on an online Greek resource (Protopapas et al., 2012). There is no Greek data base that provides ratings for concreteness. We thus relied on a rich English data base of 40.000 words (Brysbaert et al., 2014), which contained the equivalent words to the Greek ones selected for the task. The 200 words were further divided into two sets of 100 words each (lists A and B), which were matched on frequency, concreteness, and length for counterbalancing purposes. In addition, 10 words were included in a practice block, and six were filler items. Four extra words appeared in the beginning of the recognition task.

The Attention-face task. The prompt question, text displays (i.e., target: males, target: females), and other stimuli (i.e., +, ?) appeared in white 18-point Courier New Greek font on a black background. The stimuli consisted of 660 black-and-white photos of frontal views of young (i.e., 18-40 years old), and old (i.e., 59-79 years old) males and females displaying neutral emotional expressions. Face stimuli were retrieved from the FERET database of facial images (Phillips et al., 1998) and the Productive Aging Lab Face Database (Minear & Park, 2004). All photographs were edited using Adobe Photoshop 8.1 software, and corrected for luminosity, contrast, and size. We then created four subsets of 165 photos each with distinct age/gender combinations (young/female, young/male, older/female, older/male) for counterbalancing purposes.

Design and procedure

The Memory-word task. The task was a Greek adaptation of the one used by Vivas et al. (2016) in Spanish. It combined the directed forgetting paradigm with words, as used by Alonso and Diez (2000), with an emotional evaluation task. The task consisted of two phases in two separate blocks. In the first, *study & evaluation* phase (see Figure 1), each trial consisted of a fixation point (+), followed by a word; each one presented for 1 sec. Then, in half of the trials, the word was followed by the memory instruction *remember* (*ΘΘΘΘ – Θ* is the initial of the Greek word equivalent to *remember*), and in the other half it was followed by the instruction *forget* (*ΞΞΞΞ – Ξ* is the initial of the Greek word equivalent to *forget*). The memory instruction was presented for one second after a black screen of same presentation duration. Finally, in half of the trials (equally distributed to the two memory instruction conditions), the memory instruction was followed by a blank screen, and then, by the word to be evaluated (each presented for a second). Then, the evaluation prompt appeared for another second. Finally, the pleasantness evaluation scale appeared on the screen until response or for four seconds. Participants were asked to indicate how pleasant they found each word, on a scale from *1* (*very unpleasant*) to *7* (*very pleasant*). Because only half of the words were evaluated, participants could not anticipate evaluating a certain item.The study phase consisted of 106 trials; the first and the last three trials included fillers and were not analysed.

The instructions for the first study phase were as follows: “This is a memory task. Each time, a word will appear on the screen, and right after that a different instruction will appear depending on whether you will be later asked about this word or not. Specifically, if a word is followed by the instruction *remember* (*ΘΘΘΘ* - in Greek), you need to learn this word because we will ask you about it later. However, if a word is followed by the instruction *forget* (*ΞΞΞΞ* - in Greek), you do not need to learn the word because we will not ask you about it later on. It is very important to follow the instructions given. Notice, that forgetting information that is not necessary in the task (namely, the words followed by the instruction *ΞΞΞΞ*), will allow you to perform better. This is because forgetting is an adaptive mechanism that allows us to cope with situations in which we are asked to remember a lot of information. Consequently, forgetting is necessary for smooth functioning of our cognitive system.

In addition, we are interested to learn characteristics of certain words; specifically, if some of the words presented are more or less pleasant to you. For this reason, after some of the words accompanied by the instruction (*ΞΞΞΞ* or *ΘΘΘΘ*), a scale, ranging from 1 to 7, will appear on the screen. You can press *1,* if you think that the word presented is *very unpleasant,* or *7,* if you find the word *very pleasant*. You can also press any number in between to show exactly how pleasant you find the word. You will have to answer as quickly as possible since the scale will disappear after four seconds.”

In the second, *recognition* phase, 200 words (the 100 presented in the *study & evaluation* phase, and 100 new) were presented randomly, along with four filler words that appeared at the beginning of the task. Each trial consisted of the presentation of a fixation point (1 sec), followed by a word (300 msec), and finally, by a screen with the instruction *respond* (remaining until response). Participants were asked to press *K* if they remembered the word presented, and *D* if they did not. The word lists (study and new), and the response-key mapping were counterbalanced across participants.

The instructions for the second, *recognition* phase were as follows: “All the words have now been presented. Next comes the memory task: specifically, a word recognition task. You will have to remember ALL the words that you saw, that is the words followed by the instruction *ΘΘΘΘ* and the words followed by the instruction *ΞΞΞΞ*. To indicate whether you remember a word or not, press the keys *D* and *K*, accordingly.” At the end, based on Vivas et al. paradigm (2016), participants were asked to respond to the following four questions using a 7-point scale (*totally disagree-totally agree*): 1.“Generally, I associated the words followed by the instruction *forget* (*ΞΞΞΞ*) with something negative”; 2. “Generally, I associated the words followed by the instruction *remember* (*ΘΘΘΘ*) with something positive”; 3. When I saw the instruction *forget* (*ΞΞΞΞ*), I evaluated the word more negatively without thinking about its meaning, simply because I associated the instruction *forget* with something negative”; 4. “When I saw the instruction “remember” (*ΘΘΘΘ*), I evaluated the word more positively without thinking about its meaning, simply because I associated the instruction *remember* with something positive.”

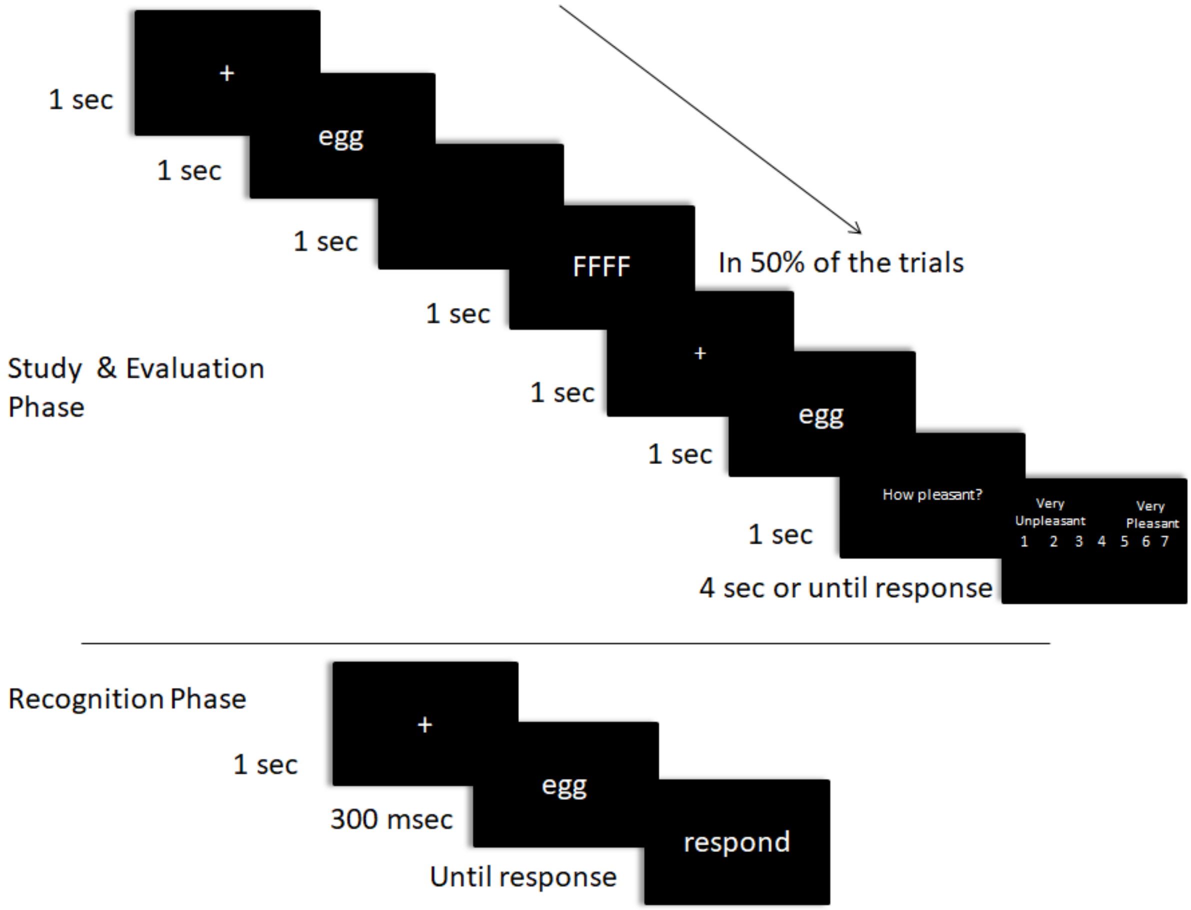

Figure 1. Sequence of events in memory-word task trial.

The Attention-face task. The task consisted of a practice block, and two experimental blocks, which started with a prompt indicating what gender to select (female vs male). The order of the female and male blocks was counterbalanced across participants. In each block, a trial (see Figure 2) started with a central fixation cross remaining on screen for 600msec. Then two photos depicting faces were presented to the right and left of fixation for 300 msec. On 60% of the trials the male and female faces were matched for age (i.e., both young), and mismatched on the remaining 40% of the trials. Then, stimuli were replaced by a blank screen until response. Participants were instructed to attend to the target face (female or male, depending on the prompt) and indicate its age, by left- or right-clicking on the mouse with their dominant hand. The age-click mapping was counterbalanced across participants. The response was followed by a central fixation cross for 500 msec. Then the prompt question *How pleasant?* was presented for 1500msec and a photo appeared in the centre of the screen until response. It depicted either the target face presented during the attention task (*target* condition), the distractor face (*distractor* condition), or a new face of the same sex and age with either the attended faces (*novel target* condition), or the ignored faces (*novel distractor* condition). Participants were instructed to evaluate each face photo presented on a scale ranging from *1 (very unpleasant)* to *7 (very pleasant)*. There were 30 trials for the attended and ignored conditions, and 40 trials for the novel conditions.

The order of the memory-word and attention-face tasks was counterbalanced across participants.

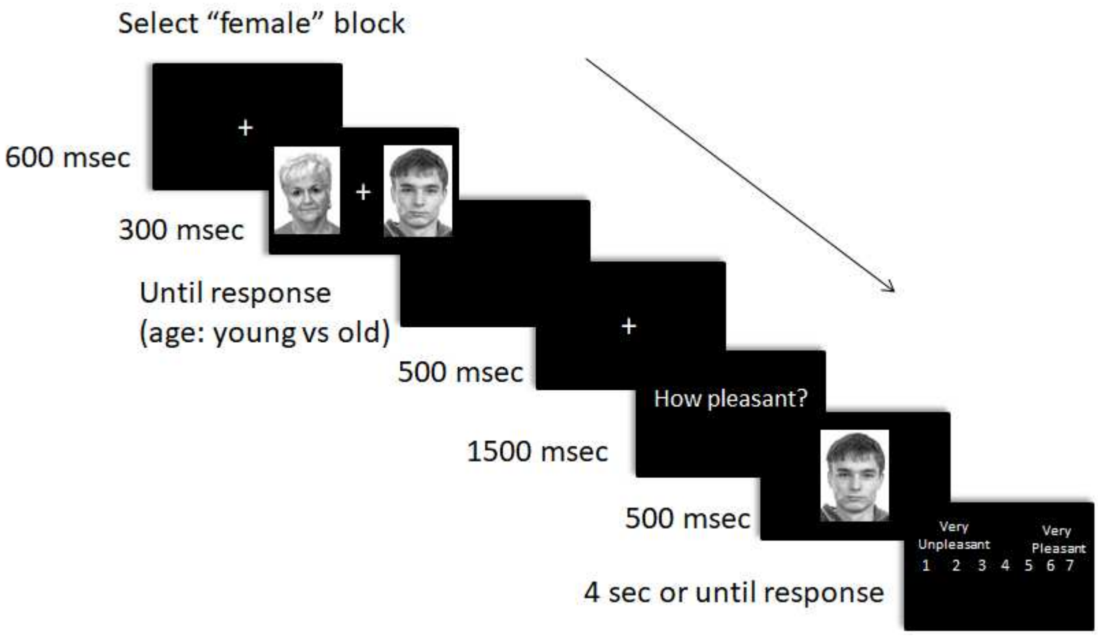

Figure 2. Sequence of events in a mismatch trial of the attention-face task

Results

Memory-word task

One participant was not included in the analyses, since mean accuracy for the recognition task was below .33 in all conditions.

Recognition Memory task. Mean accuracy rates were submitted to a 3 x 2 ANOVA with Age group (Younger Adolescents, Older Adolescents, and Young Adults) as the between-subjects factor and Condition (To-be-remembered and To-be-forgotten) as the within-subjects factor (see Table 1). The results showed significant main effects of Age group, $F(2, 79) = 5.57$, $p = .005$, $\eta^2 = .124$, and Condition $F(1, 79) = 73.95$, $p < .0001$, $\eta^2 = .483$. That is, there was worse mean recognition accuracy for the to-be-forgotten items (.59) than for the to-be-remembered items (.70), and for younger (.59) and older (.62) adolescents relative to young adults (.71; LSD post-hoc comparisons test yielded $p =.003$ and $p =.016$, respectively). There was also a significant Age group by Condition interaction, $F(2, 79) = 3.76$, $p = .028$, $\eta^2 = .087$. A one-way ANOVA with the directed forgetting effect (to-be-remembered accuracy minus to-be-forgotten accuracy), and LSD post-hoc comparisons, showed that the magnitude of the effect was significantly smaller in younger adolescents relative to the older adolescent and the young adult groups ($p = .020$ and $p =.018$, respectively). The older adolescent and young adult groups did not differ from each other, $p = .926$. Younger adolescents significantly differed from adults on recognition accuracy for both conditions, to-be-remembered (.62 vs .77) and to-be-forgotten (.56 vs .65); however, the difference was greater in the to-be-remembered condition ($p < .0001$ and $p =.052$, respectively). Thus, relative to the overall worse recognition, recognition in the to-be-forgotten condition was better than expected in the youngest group. Recognition in the to-be-remembered condition, for the adolescence group, was above chance levels, $t(24)= 3.68$, p =.001.

Word Evaluation task. Mean pleasantness scores were submitted to a 3 x 2 ANOVA with Age Group as the between-subjects factor, and Condition as the within-subjects factor (see Table 1). Results showed significant main effects of Age Group, $F(2, 79) = 4.52$, $p = .014$, $\eta^2 = .103$, and Condition, $F(1, 79) = 22.11$, $p < .0001$, $\eta^2 = .219$. That is, words to-be-forgotten (4.17) were evaluated less pleasantly than those to-be-remembered (4.27), indicating an emotional devaluation of items that were instructed to be forgotten. Moreover, younger (4.27) and older adolescents (4.17) overall evaluated the words more positively relative to young adults (3.85, $p = .006$ and $p = .034$, respectively). The interaction did not reach statistical significance, $F < 1$.

Analyses based on responses to questions. We formed two subgroups based on ratings for each question regarding the affective state associated with the memory instruction; a *Low-affect encoding* group and a *High-affect encoding* group consisted of participants with ratings between 1-3, and 5-7, respectively. Participants with neutral responses (ratings of 4) were not included in the analyses. We then conducted four planned independent sample t-tests to compare the magnitude of the devaluation effects (to-be-remember ratings minus to-be-forgotten ratings) in participants who associated a positive value to the instruction *remember* (*High-affect encoding* group for questions 2 and 4) relative to those who didn't (*Low-affect encoding* group for questions 2 and 4); and to compare those who associated a negative value to the instruction *forget* (*High-affect encoding* group for questions 1 and 3) with those who didn't (*Low-affect encoding* group for questions 1 and 3). None of the comparisons reached statistical significance: Question 1 [$N_{High\text{-}affect} = 22$ vs $N_{Low\text{-}affect} = 32$; $t(52) = .112$, $p = .911$], Question 3 [$N_{High\text{-}affect} = 23$ vs $N_{Low\text{-}affect} = 48$; $t(69) = 1.06$, $p = .294$], Question 2 [$N_{High\text{-}affect} = 48$ vs. $N_{Low\text{-}affect} = 21$; $t(67) = .44$, $p = .156$], and Question 4 [$N_{High\text{-}affect} = 29$ vs $N_{Low\text{-}affect} = 39$; $t(66) = 1.75$, $p = .086$]. Regarding Question 4 only, although the devaluation effect was significant in both groups [$t(38) = 2.35$, $p = .024$ and $t(28) = 3.83$, $p = .001$, respectively], there was a near significance tendency for the magnitude to be greater in the *High-affect encoding* group, which associated a positive value to the instruction *remember* (.428) than in the *Low-affect encoding* group (.192).

To test if there were differences between the age groups in response to the questions, we then submitted the ratings to one-way ANOVAs with age group as the between-subject factor. The main effect of age group reached statistical significance only for Question 2, $F(2, 79) = 3.89$, $p = .025$, $\eta^2 = .090$. LSD post-hoc comparisons showed significantly higher scores in the younger adolescent (5.24) relative to the older adolescent (4.24, p =.033) and the young adult (4.09, p =.010) groups, which did not differ from each other (p = .738). That is, younger adolescents responded more positively to the statement: "Generally, I associated the words followed by the instruction *remember* (*ΘΘΘΘ*) with something positive." Actually, 80% of the younger adolescents had scores between 5-7 (High-affect encoding group) relative to 48% and 40% of the older adolescents and young adults, respectively.

Table 1. *Mean accuracy for the Memory-word task, as a function of Memory instruction and Age group; mean response times and accuracy as a function of Age group and Target age in the attention-face task; and mean rating scores as a function of Age group, and Memory instruction in the Memory-word task or Condition in the Attention-face task. Standard deviations are within parenthesis.*

Memory-word task	TBR	TBF	
Recognition Task	Accuracy		DFE
Younger Adolescents.	.62 (.16)	.56 (.17)	.05*
Older Adolescents	.68 (.15)	.55 (.17)	.12†
Young Adults	.77 (.13)	.65 (.17)	.12†
Word Evaluation Task	Ratings		DE
Younger Adolescents	4.40 (.76)	4.13 (.80)	.27*

Older Adolescents	4.32 (.48)	4.01 (.43)	.31*
Young Adults	3.98 (.66)	3.71 (.50)	.27*

Attention-face task			Older-faces		Younger faces	
Attention Search task	RTs	Accuracy	RTs	Accuracy	RTs	Accuracy
Younger Adolescents	1002 (332)	.70 (.18)	1036 (373)	.69 (.22)	979 (336)	.66 (.24)
Older Adolescents	941 (181)	.85 (.10)	930 (176)	.88 (.09)	958 (201)	.82 (.16)
Young Adults	933 (243)	.89 (.15)	842 (272)	.91 (.09)	933 (232)	.86 (.19)
Face Evaluation Task		Ratings				
	Target	Distractor	Novel	DE		
Younger Adolescents	4.21 (.69)	4.07 (.69)	4.05 (.82)	.14		
Older Adolescents	4.20 (.78)	4.05 (.79)	4.03 (.79)	.15		
Young Adults	3.96 (.85)	3.89 (.82)	3.81 (.77)	.07		

Note: TBR = To-be-remembered; TBF = To-be-forgotten; DFE (*Directed Forgetting Effect*) = TBR Accuracy minus TBF Accuracy; DE (*Devaluation Effect*)= Rating scores for TBR/Target minus Rating scores for TBF/Distractor; **p* < .05; †*p*< .001.

Attention-face task

Four older adolescents and one young adult did not complete the task, and one younger adolescent was not included in the analyses, having mean accuracy below .33.

Attention search task. Accurate mean response times were submitted to a one-way ANOVA with age group as the between-subjects factor (see Table 1). The main effect of age group did not reach statistical significance, $F(2, 74) = .52$, $p = .594$, $\eta^2 = .014$. However, the ANOVA with accuracy data yielded a significant age group effect, $F(2, 74) = 13.62$, $p < .001$, $\eta^2 = .269$. LSD post-hoc comparisons showed that younger adolescents (.70) had significantly lower accuracy relative to older adolescents (.85, p< .001) and adults (.89, p < .001), who did not significantly differ ($p = .345$).

To investigate a potential interaction of age group with target face age (an *own-age* effect) on task performance, we conducted two separate 3 (Age group) x 2 (Target age: young vs old) ANOVAs with correct response times, and accuracy data (see Table 1). Result with response times did not yield significant effects, F (2, 74) = .547, p = .581, η^2 = .015, F (1, 72) = .404, p = .527, η^2 = .005, and F (2, 72) = 1.38, p = .259, η^2 = .036, for the main effects of Age group, Target age, and their interaction, respectively. Results with accuracy, showed significant main effects of Age group, F(2, 74)= 16.53, p < .001, η^2 = .309, and Target age, F(1, 74) = 3.91, p = .052, η^2 = .050. That is, overall accuracy was better for older faces (.83) than for younger faces (.78). The two-way interaction did not reach statistical significance, F(2, 74)= .208, p =.813, η^2 = .006.

Face Evaluation Task. Mean evaluation ratings were submitted to a 3 x 3 mixed ANOVA with Age group as the between-subjects factor and Attention condition (target, distractor, novel) as the within-subject factor (see Table 1). Results showed a significant main effect of Attention condition, F(2, 148) = 4.72, p = .010, η^2 = .060. LSD post-hoc comparisons showed that distractor faces (4.00) were overall rated significantly less pleasant than target faces (4.12; p =.013), that is we found a significant distractor devaluation effect. Novel faces (3.97) were also overall rated significantly less pleasant than target faces (p = .008). No other comparison reached statistical significance, *ps* >.05. Neither the main effect of age group, F(2, 74) = .83, p = .439, η^2 = .022, nor the age group by attention condition interaction, F(4, 148) = .127, p = .972, η^2 =.003 reached statistical significance.

Correlations between the tasks

To investigate the relationship between the memory and the attention tasks, we conducted bivariate Pearson correlations between accuracy and RTs measures and devaluation effects in the overall sample. Results showed significant positive correlations between accuracy in the attention-face task and in both conditions of the memory-word task, *r*(76)= .406, *p* <.001, and *r*(76) = .328, *p* = .004, for the to-be-remembered, and the to-be-forgotten conditions, respectively. The devaluation effects for the memory and attention tasks were not significantly correlated, *r*(76) = .022, *p* =.849 (see Table 2).

Table 2. *Correlations between the memory-word and attention-face tasks in the Greek overall sample.*

	1.TBR-Accuracy	**2.TBF-Accuracy**	**3.Attention-Accuracy**	**4.Attention-RTs**	**5. DE-Memory**	**6. DE-Attention**
2.	.794*					
3.	.406*	.328*				
4.	-.085	-.050	-.136			
5.	.043	.005	-.160	.132		
6.	-.035	.093	-.046	-.002	.022	

Note. TBR=To-be-remembered; TBF=To-be-forgotten; DE=Devaluation effect; *p<.01.

Discussion

The present study investigated for the first time the interaction between inhibition of distracting, unwanted information and affective evaluation in younger and older adolescents, as well as young adults. We predicted that intentionally forgotten words and distractor faces would be emotionally devaluated in all age groups, and that adolescents would perform worse in the memory and attention tasks, relative to the group of young adults, reflecting ongoing development of controlled inhibitory processes during adolescence. Based on the devaluation-by-inhibition hypothesis (Fenske & Raymond, 2006; Raymond et al., 2003), and the evidence supporting a positive relationship between the strength of inhibition and the magnitude of the subsequent affective devaluation (Kiss et al., 2008; Martiny-Huenger et al.

2014; Raymond et al., 2003, 2005), we further predicted that more efficient inhibition in young adults should result in greater in magnitude emotional devaluation effects.

In line with our predictions, we found an overall significant emotional devaluation of intentionally forgotten words, as well as of distractor faces. Specifically, the latter were evaluated less positively than target faces (Goolsby, Shapiro, Silver, et al., 2009; Raymond et al., 2005), but not relative to the novel baseline faces (Raymond et al., 2003, 2005; Martiny-Huenger et al., 2014). Target faces were also evaluated more positively than novel faces, which is not surprising since novel faces were not influenced by the mere exposure effect. To-be-forgotten words were also evaluated less positively than to-be-remembered words (Vivas et al., 2016), supporting the robustness of the *Forgetting devaluation effect*. We also found that younger adolescents had significantly worse performance in both tasks relative to older adolescents and young adults; namely, lower overall accuracy in the attention search task, and worse overall accuracy in the memory tasks, and smaller in magnitude directed forgetting effects. The key finding of our study is that although younger adolescents had worse performance in two tasks involving controlled inhibitory processes, the magnitude of the devaluation effects was not influenced by age group.

These findings seem to be in contradiction with the inhibitory account of the devaluation effect, neither do they agree with previous studies that suggest a proportional relationship between attention inhibition and the magnitude of devaluation effects (Kiss et al., 2008; Martiny-Huenger et al., 2014; Raymond et al., 2003, 2005). One difference between these studies and the present one, is that while they manipulated the amount of interference, hence inhibition, we adopted a developmental approach, and compared age groups under the same interference conditions. As far as we know, only two studies have compared samples expected to differ in selective attention and inhibition abilities, yet focusing on patient populations, rather than typical development. Strauss et al. (2012) found that patients with schizophrenia had significant distractor devaluation effects, but worse accuracy relative to matched control participants in the search task, suggesting decreased inhibition or less efficient selective attention. On the other hand, Tillem and Baskin-Sommers (2017) reported stronger distractor devaluation effects, but only relative to the novel stimuli, in a group of individuals who scored high in psychopathy traits, which have been associated with enhanced selective attention. Thus, studies comparing populations with worse/better selective attention capacity have not yielded conclusive results. Such findings cannot be directly compared to those stemming from studies with typically developing, healthy populations. Yet, the converging present results from two different tasks involving inhibition seem to point to a similar direction with the Strauss et al., (2012) findings, regarding a sample of patients with less efficient selective attention and inhibition; that is that the latter does not result in diminished emotional devaluation.

Alternatively, other processes, specific to each task, might have actually contributed to our results, and specifically, to the worse performance of the younger adolescents and therefore, the lack of interaction between age and affective devaluation. We selected the specific cognitive tasks because they both involve controlled inhibitory processes. The hypothesized task commonalities were supported by the significant positive correlations in the accuracy measures in the whole sample. The moderate to low correlations observed are also consistent with the generally low in strength correlations typically reported for executive function tasks tapping on controlled processes (Miyake et al., 2000). Yet, despite the two task measures being related, we did not find significant correlations between the attention and memory devaluation effects. This however also seems supportive of the aforementioned conclusion: that the shared mechanism, namely inhibition, may not be solely driving the observed devaluation effects. Alternatively, lack of correlation between devaluation effects may also be related to the different inhibition types tapped by the tasks; that is, a more automatic form involved in focused selective attention, versus a more effortful suppression that might have been required in the directed forgetting paradigm (Kok, 1999). Whether different forms of inhibition, as inferred from different experimental paradigms, reflect qualitatively distinct processes, remains an unresolved question (Kok, 1999; Miyake, 2000). To our knowledge, there are no studies comparing the magnitude of the devaluation effects as a function of inhibition type. In the present study, the estimated effect size for the devaluation effect in the memory task was greater than the one for the attention task; indicating that the former may actually constitute a more robust effect. Future studies may investigate these issues systematically.

In addition, requirements for discrimination of the age of a target face (young vs old), may have rendered the attention task more difficult for the adolescents relative to the young adult participants. For instance, studies support that we are faster and more accurate in recognizing faces of people closer to our own age (the *own-age effect*; e.g., Ebner & Johnson, 2011). Thus, one could argue that younger adolescents were less good at discriminating the age of the faces, which could explain the lower accuracy in the attention task for this group. However, when we analysed responses as a function of target face age (young vs old), we did not find evidence supporting own-age effects influencing performance generally, or in the younger adolescent group, in particular. Actually, we only found a significant effect with accuracy in the overall sample in the opposite direction predicted by the own-age effect; accuracy was better for older faces than for younger faces. Furthermore, although task difficulty in terms of attentional selection (e.g., greater similarity between target and distractor based on target description) has been related with the strength of inhibition (Houghton and Tipper, 1994), there is no evidence indicating that lower target discriminability leads to greater inhibition. On the contrary, Middlebrooks and Schall (2014) suggested that difficulty of perceptual discriminability is functionally independent from response inhibition processes. We would also like to notice, that attentional selection of the target was based on gender and not on age, and to our knowledge there is no research supporting that gender perception may be modulated by age. Finally, evaluative/affective judgements do not seem to be affected by the *own-age effect* since older people are viewed more negatively than younger people by both younger and older persons (Ebner & Johnson, 2011). Thus, potential age differences in age perception should not influence emotional devaluation effects. Our study does not rule out, however, that other processes possibly affected by development (e.g., encoding efficiency, response control, vigilance) may have influenced performance on the tasks.

We suggest that worse performance (lower accuracy) in the attention task by younger adolescents, relative to older adolescents and young adults, is consistent with evidence showing that attentional control and inhibitory skills are not fully refined in early adolescence (at least until the age of 15; Huizinga et al., 2006; see also Best & Miller, 2010). These findings are possibly linked to the on-going myelination of nerve fibres and maturation of brain structures (frontal lobe) supporting inhibitory control (see discussion in Anderson et al., 2001). With regard to the memory task, we found a smaller directed forgetting effect in the youngest group due to better than expected recognition for the to-be-forgotten words, and taking into account their overall worse recognition accuracy. The latter finding is also consistent with previous studies demonstrating worse inhibitory control of irrelevant representation in younger children (Bjorklund & Harnishfeger, 1990), particularly when the task used imposed substantial cognitive demands (e.g., Kliegl et al., 2017), as was actually the case with our memory-words task.

Could other non-inhibitory accounts of devaluation effects explain our key finding of similar devaluation effects despite observation of age differences in the attention and memory selection tasks? As we discussed in the introduction, Dittrich and Klauer's (2012) hypothesis is based on specific affective states associated in our case with the instructions (*attend/remember* vs *ignore/forget*), resulting in biased evaluation responses. Thus, this hypothesis does not predict differences in the magnitude of devaluation effects as a function of the amount of interference or the efficiency of controlled inhibitory processes. In partial support of this explanation, we found a marginally significant tendency for the magnitude of the devaluation effect in the memory task to be bigger in the group that associated positive affective states with the instruction *remember* relative to the group that didn't (analyses of question 4). However, the devaluation effect was still significant in the *low-affect encoding* group. Furthermore, as in Vivas et al. (2016), we employed *forget* instructions that intended to induce positive affect, and still found significant devaluation effects of the to-be-forgotten words in all age groups. Finally, affective encoding was found intensified in adolescents (both groups rated overall neutral words as more positive, and the younger adolescents attributed more often positive affective states to the *remember* instruction) relative to young adults. This is consistent with evidence suggesting intensification of both affective (positive and negative) and motivation experiences by mid adolescence (Crone & Dalh, 2012). However, despite such intensification, the devaluation effect was not stronger in the former.

One possibility is that the inhibition and affective encoding explanations are not mutually exclusive; and that several processes, including *mere exposure*, may in principle contribute to devaluation effects (see also Inoue & Sato, 2017, for results that do not fit the inhibition or the affective encoding explanations). This could explain why we found a tendency for bigger devaluation effects when a positive affective state was associated with the instruction "remember", as self-reported by participants. And it would also explain why a significant devaluation effect was observed even when participants did not associate an affective state to the instruction. Furthermore, this may explain our pattern of findings if we further assume that the interaction between these processes is modulated by development.

That is, the intact and adult-like devaluation effects observed in younger adolescents, who were less efficient in inhibitory control, could actually be driven to a greater extent by affective encoding in that age group (in line with the intensification hypothesis discussed above), relative to the older adolescent and young adult participants who are characterized by more refined inhibitory processes (see Anderson et al., 2001; Crone & Steinbeis, 2017).

Unfortunately, we could not test directly this hypothesis since we did not have sample sizes big enough to explore devaluation effects as a function of both age group and question 4 group. However, younger adolescents reported significantly higher association of the instruction *remember* with a positive affective state. Moreover, eye inspection of the data suggests that the tendency for a greater in magnitude devaluation effect in the *High-affect encoding* group (question 4) could actually be driven by the younger adolescent group (see Figure 3; should be interpreted with caution given small sample sizes). As suggested by the relevant literature, adolescence and particularly the early adolescence years, which are closely associated with the onset of puberty, are characterised by heightened emotion and affect (Crone & Dalh, 2012; Giedd, 2015), yet also by poorer regulatory mechanisms, including those relying on inhibitory control (see also Curtis, 2015; Dahl, 2004). This combination may allow for greater modulation of cognitive processes and behaviour by emotions - as well as vice versa - relative to the young adulthood phase (see Steinberg, 2005). Although, we could not test this hypothesis, based on our observations, we suggest that emotional devaluation of ignored and intentionally forgotten information may be driven more strongly by affective encoding in younger adolescents. This is though a tentative hypothesis that needs to be tested in future studies.

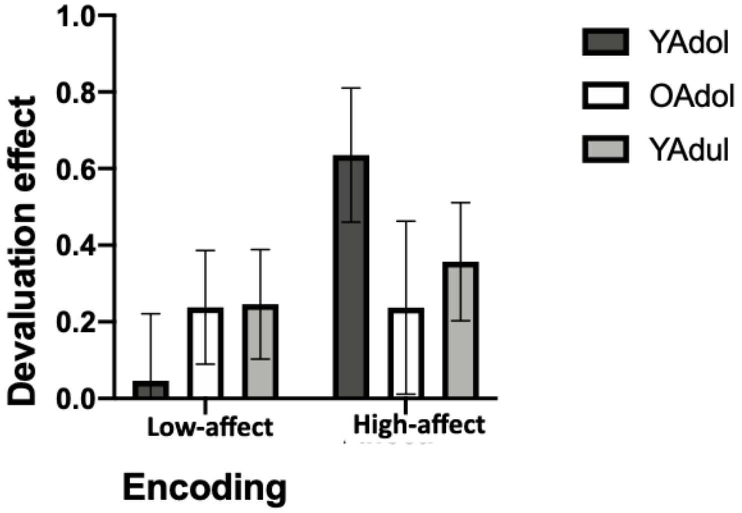

Figure 3. Devaluation effect (Evaluation scores for To-be-remember words – Evaluation scores for To-be-forgotten words) as a function of Question 4 group (Low-affect vs High-affect Encoding), and Age group (YAdol= younger adolescents, OAdol=older adolescents, and YAdul= young adults).

In conclusion, our findings suggest that adolescence is a sensitive period for the development of inhibitory control in attention and memory selection. Mechanisms responsible for efficiently ignoring distracting stimuli and intentionally forgetting unwanted items are not refined before middle- to late adolescence (see Anderson et al., 2001; Best & Miller, 2010; Best et al., 2009; Crone & Steinbeis, 2017; Luna et al., 2004). Despite less efficient inhibitory control capacity in younger adolescents, the present study also shows for the first time that ignoring and (intentional) forgetting lead to subsequent emotional devaluation across adolescence and young adulthood. However, our findings do not fully support an inhibition account of the devaluation effects. Future studies could shed further light into the cognition - affect interplay as a function of age and particularly, adolescent development.

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