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Aging and motivated cognition: the positivity effect in attention and memory

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As people get older, they experience fewer negative emotions. Strategic processes in older adults' emotional attention and memory might play a role in this variation with age. Older adults show more emotionally gratifying memory distortion for past choices and autobiographical information than younger adults do. In addition, when shown stimuli that vary in affective valence, positive items account for a larger proportion of older adults' subsequent memories than those of younger adults. This positivity effect in older adults' memories seems to be due to their greater focus on emotion regulation and to be implemented by cognitive control mechanisms that enhance positive and diminish negative information. These findings suggest that both cognitive abilities and motivation contribute to older adults' improved emotion regulation.

Introduction

There are reasons to believe that well-being should decline as people get older. Physical health and cognitive abilities decline and the amount of lifetime remaining decreases. Yet the frequency of negative affect (emotions) decreases throughout most of adulthood and levels off around age 60 [1–3]. Positive affect remains largely stable across adult lifetime, although some studies show modest increases [3] or slight decreases [2] with age. Thus, the ratio of positive to negative affect improves through adulthood. What might explain this surprising observation across the same years that physical and cognitive health declines? In this article, we review recent findings that suggest that a greater focus on emotional goals among older adults lead them to favor positive and avoid negative information in their attention and memory. Interactions between emotion and cognition, although important to understand at all ages, might be particularly relevant for understanding and improving cognitive performance in older adults.

Cognitive control declines with age

Perhaps the most widely acknowledged psychological change with age is the decline in cognitive processes, especially memory. However, not all cognitive processes decline with age – not even all types of memory. One general characterization is that older adults have impaired cognitive control that is associated with deterioration in prefrontal brain regions [4,5]. Thus, older adults show deficits on attention and memory tasks that require the generation and maintenance of internal strategies rather than just reliance on external cues [6–8]. For example, explicit recall of words studied a few minutes previously was shown to decline across a four-year period whereas implicit memory of recently studied words did not show a decline with age [9].

Emotion regulation improves with age

In contrast with the declines seen in cognitive control, age does not impair emotional control. Compared with younger adults, older adults report that they focus more on selfcontrol of their emotions and rate their emotion-regulation skills as better [10,11]. When dealing with an upsetting interpersonal situation, older adults report being less likely to engage in destructive behavioral responses such as shouting or name calling [12]. A study that sampled participants' moods at random intervals over the course of a week found that when participants experienced a negative mood, it was less likely to persist to the next sampling occasion among older adults than younger adults, suggesting that older adults are able to dissipate negative affect more effectively than younger adults are [1].

Research with younger adults suggests that mechanisms used to regulate emotions are implemented by some of the same brain regions as mechanisms used to control cognition [13]. On the face of it, this seems paradoxical [14]. How could it be that older adults are more effective emotion regulators than younger adults but less effective in cognitive control processes involved in encoding and retrieving memories? One possibility is that although there are significant declines in strategic control processes with age, there are also shifts in how people allocate these processes in their everyday lives [15]. For example, the under-recruitment of frontal brain regions observed in older adults is eliminated when they are given instructions to use particular strategies (e.g. [16]), suggesting that at least some of the presumed aging deficits reported in the literature reflect behavioral shifts as much as fundamental neural deterioration.

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Box 1. Socioemotional selectivity theory

Socioemotional selectivity theory maintains that time horizons influence goals. When time is perceived as open-ended, goals are most likely to be preparatory, for example, gathering information, experiencing novelty and expanding breadth of knowledge. When constraints on time are perceived, goals focus more on objectives that can be realized in their very pursuit. Under these conditions, goals emphasize feeling states, particularly regulating emotional states to optimize well-being.

As an example of socioemotional selectivity theory, age differences in goals are seen when participants are asked whom they would like to spend time with. Younger adults are more likely to chose social partners that offer new information, such as a book author, whereas older adults are more likely to chose social partners likely to satisfy emotional goals, such as close friends or family members [67,68]. Time perspective is not a fixed characteristic, however, so younger adults with terminal illnesses or those who are simply asked to imagine an impending geographical relocation emphasize emotional goals as much as older adults [68,69]. Likewise, if older adults are asked to imagine that medical advances would offer them much longer lives, they are more likely to show preferences revealing knowledge-seeking goals than if they are not asked to imagine this situation [67].

Resource allocation, of course, implicates motivation. Why might people allocate more resources towards regulating emotion as they age? Socio emotional selectivity theory (see Box 1) is a lifespan theory of motivation that posits shifts in the priorities of different goals with age because time horizons become increasingly constrained [17]. As people approach the end of life, goals associated with emotional meaning and well-being become more salient whereas goals associated with acquiring knowledge for future use become less so.

Older adults' attention shows signs of emotion regulation

We fully attend to only a small portion of what is happening around us and often fail to process information that is not consistent with current goals [18]. Older adults' greater focus on regulating emotion is therefore likely to change what they pay attention to. A study supporting this possibility used a dot-probe task, in which one emotional and one neutral face appeared side by side on a computer screen for 1 s [19]. When the faces disappeared, a dot appeared behind one of the faces. Older adults were slower to indicate which side dots were on when they appeared behind negative faces than behind neutral faces, and faster when they appeared behind positive faces than neutral faces (Figure 1). By contrast, younger adults did not show any attentional biases for the faces. Age differences in attentional biases also influence which features of choice options people focus on. For example, when given a chart with information about several models of car (e.g. whether the gas mileage is good or bad) and asked which car they would choose, older adults spend a larger proportion of their time reviewing the positive features and a smaller proportion of their time reviewing the negative features than younger adults do [20] (Figure 2).

Although dwelling on negative stimuli might put one in a bad mood, it is important to detect threatening stimuli quickly. Studies with younger adults indicate that they detect threatening information more quickly than other types of information [21]. Do the age differences in emotional attention reflect a decline in older adults' ability to detect threatening information quickly? A study using a visual search task suggests not [22]. Participants were shown a series of arrays of nine schematic faces and had to indicate whether the faces in each array were all the same or not. Half the time all the faces were neutral and half the time there was one emotional face in the array. As in previous studies [23], younger adults were faster to detect discrepant faces when the facial expressions were angry than when they were sad or happy. But older adults also showed the same advantage for the threatening faces, indicating that the detection advantage for threatening stimuli is maintained among older adults.

Automatic versus controlled processes

Across the various studies discussed so far, it appears that there is no age difference in the likelihood of noticing threatening information but that older adults do not dwell

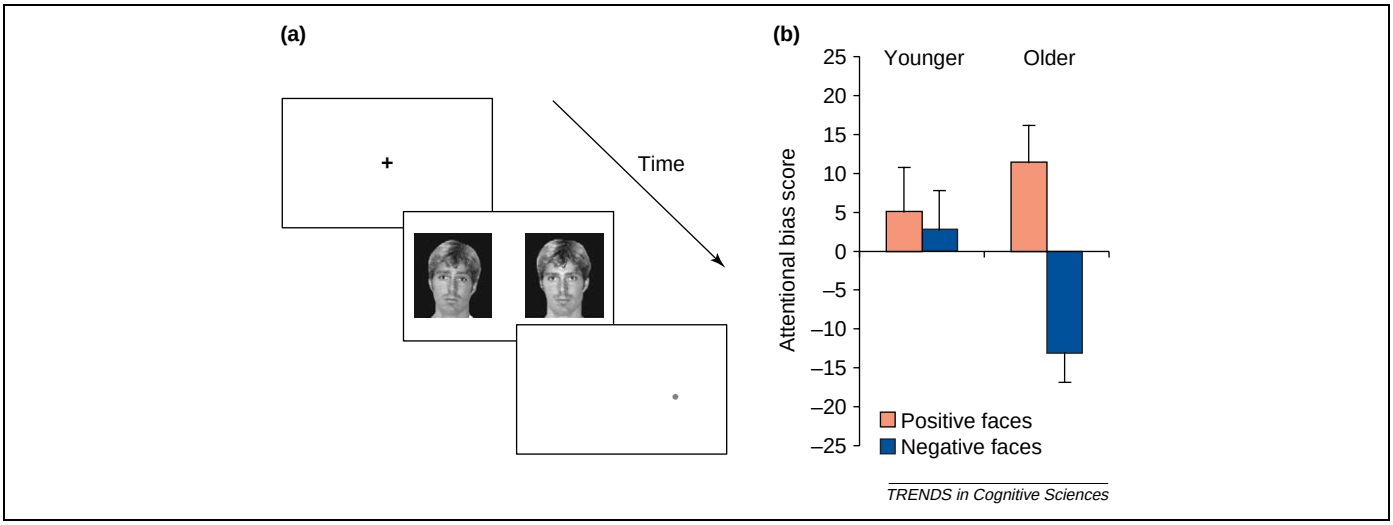

Figure 1. (a) The display in the dot-probe task [19]. After a fixation cross, two faces appeared simultaneously side by side, one emotional face (here on the left) and one neutral face (right). When the faces disappear, a dot appears in the place of one of the faces and participants are asked to respond on the basis of the emotional valence of that face. **(b)** Attentional bias scores of younger and older groups of adults. Positive scores indicate faster responses to dot appearing behind emotional faces than behind neutral faces. Older adults showed higher scores to positive faces and lower scores to negative faces than younger adults. Error bars show the standard error of the mean.

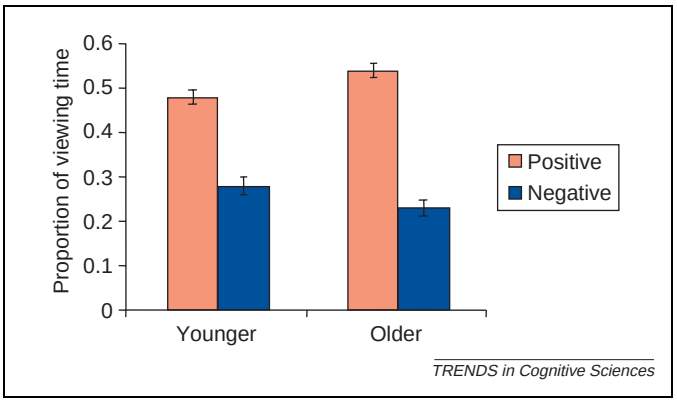

Figure 2. Total viewing time of older and younger adults for positive and negative car option features, when asked to choose a car [20]. Error bars show the standard error of the mean.

on negative information. A study using eyetracking supports this distinction between initial detection and sustained attention [24]. When a negative and a neutral picture were displayed together, both younger and older adults were more likely to glance initially at the negative picture. But younger adults looked longer at the negative pictures than the older adults did. By contrast, there were no age differences when the two pictures were positive and neutral; both age groups showed greater sustained attention to the positive than the neutral picture.

Both automatic and controlled processes influence attention to emotional stimuli [25]. Goal-directed control processes help select information to attend to or to ignore. However, potentially threatening or aversive stimuli receive preferential processing even when attention is limited, indicating that emotion can direct attention even when one's current goals are directed elsewhere. As outlined in Table 1, we hypothesize that emotional attention and memory reveal age differences when goal directed controlled processes are involved, but not when only automatic processes contribute to the effects.

In summary, the literature on emotional attention and aging suggests that automatic emotional attention processes, such as threat detection, change little with age. By contrast, attentional processes that are more influenced by top-down control reveal age differences in which older adults attend more to positive information than negative information.

Older adults' memory also shows influence of emotion regulation

Like attention, memory is selective. As attended information is more likely to be remembered than nonattended information, initial attention provides one filter of the incoming information stream [26]. Older adults' attentional biases reviewed in the previous section should therefore influence what gets encoded. Goals also influence how memories are reconstructed later [27–30], so emotional goals would be expected to lead older adults to distort their memories in a positive direction more than younger adults.

Memory for choices and emotional stimuli

These possibilities are supported by findings from studies that examined age differences in emotional memory. In one study, groups of younger and older adults were asked to make a series of hypothetical choices, each between two options that had some positive and some negative features [31]. When remembering past choices, one way to regulate emotion is to remember one's chosen option as having more good features than the rejected options did. When later asked to indicate which option features had been associated with, older adults showed more choice supportive memory than younger adults, attributing more positive features to chosen options and more negative features to rejected options. However, if younger adults were asked to focus on their feelings after making the choices, their later memories were just as choice supportive as those of older adults. Thus, younger adults do not seem to focus on emotional goals unless reminded to do so by some external cue.

Age differences are also sometimes found in memory for emotional pictures [32], words [33] and faces [19,34]. For instance, when participants viewed a picture slide show without any instructions about how to encode the pictures, an age by valence interaction occurred in later recall and recognition [32]. Although older adults were less likely to remember the pictures overall, the age difference was greatest for the negative pictures and smallest for the positive pictures (Figure 3). These positivity effects were consistent across men and women, African- and European-Americans, and people of low and high socioeconomic status. One recent study of working memory for emotional material (Mikels, Larkin, Reuter-Lorenz and Carstensen, unpublished) indicates that in some cases, positivity effects can even lead older adults to show superior memory performance than younger adults. In this study, older adults outperformed younger adults when the working memory task involved positive stimuli whereas younger adults outperformed older adults when the task involved negative stimuli.

Table 1. Automatic vs controlled processes affecting emotional attention and memory

Nature of emotional influence on cognition	Associated brain regions	Impact of emotion-regulation goals	Relevance for emotional attention	Relevance for emotional memory
Automatic, bottom-up	**Amygdala:** shows relatively little decline with age [14,61,62]	None or very little	Arousing (especially threatening) information is noticed quickly by both younger and older adults, no age differences seen in this threat/arousal detection advantage [22,24]	Enhancement in memory for arousing stimuli is as large for older adults as it is for younger adults [32,36–38]
Goal-directed, top-down, subject to cognitive control	**Prefrontal brain regions:** show significant decline with age, reducing cognitive control abilities [4,5]	Significantly affected by emotional goals; extent of influence of these goals is constrained by the effectiveness of cognitive control processes	Older adults attend less to negative stimuli and as much or more to positive stimuli as younger adults do [19,20,24]	A smaller proportion of what older adults remember is negative [19,32–34] and their memories are more likely to be distorted in a positive direction [31,39,40,42]

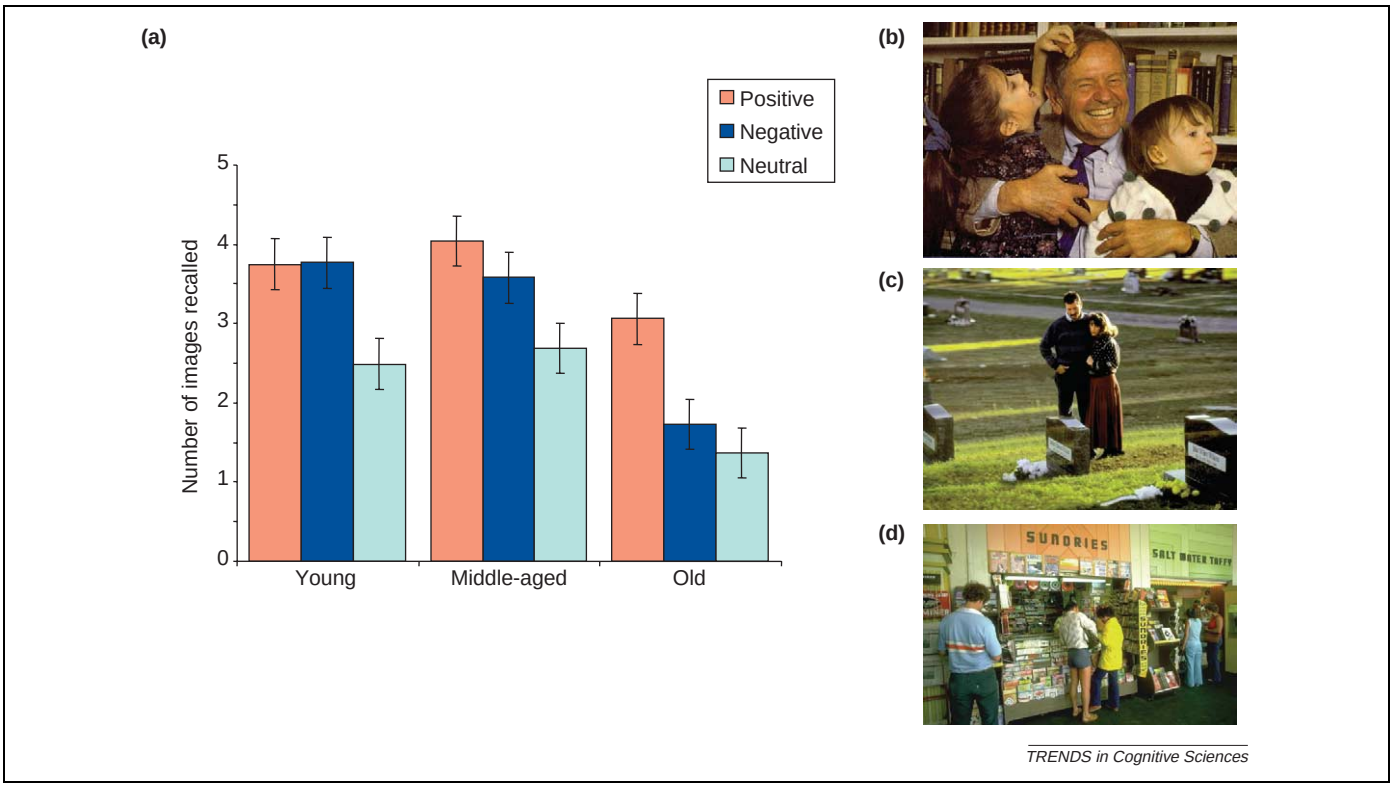

Figure 3. **(a)** Total number of pictures recalled by younger (18–29 years old), middle-aged (41–53 years old), and older (65–80 years old) adults [32]; examples of **(b)** positive, **(c)** neutral and **(d)** negative pictures seen in the experiment. Error bars show the confidence interval for the age-by-valence interaction.

By contrast, some studies that examined memory for emotional stimuli found no interactions of valence and age [35–37] or only a marginally significant one [38]. One possibility is that the specific encoding tasks given in these studies (typically to rate or focus on the emotional characteristics of the stimuli) limited the influence of emotional goals. Open-ended encoding sessions might be more likely to show the effects of emotional goals. It also seems likely that the more personally relevant the information is, the more likely older adults would be to attempt to implement emotion-regulation goals when processing the information.

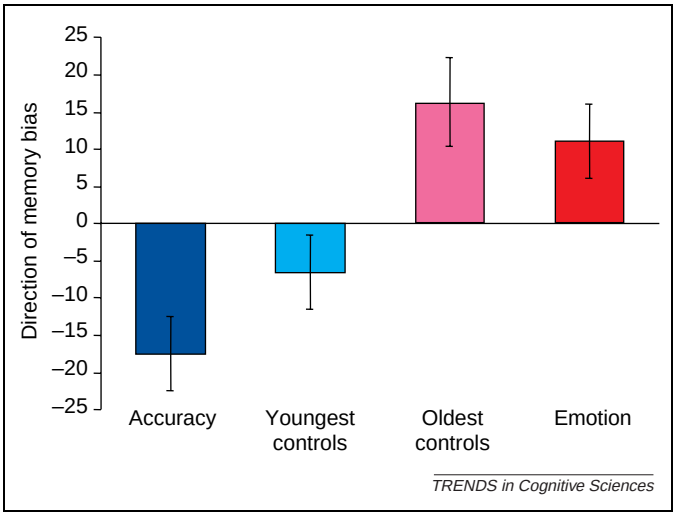

Figure 4. Degree of positive or negative memory distortion for nuns answering various questions about their health and well-being 14 years ago [42]. For example, the nuns were asked, '*How often were you completely worn out at the end of the day*?' and '*How often did you experience happiness*?' Participants in the control condition simply filled out the memory questionnaire. In the accuracy condition, they were repeatedly queried about the memory strategies they were using and in the emotion condition they were repeatedly queried about their current emotions as they completed the questionnaire. The bias scores reflect a comparison of the nuns' remembered health and well-being to their actual ratings 14 years ago. Memories that were more positive than the actual ratings yielded positive scores whereas those that were more negative yielded negative scores. Error bars show the standard error of the mean.

Autobiographical memory

Of course, the most personally relevant type of memory is autobiographical. Several studies reveal positivity effects in older adults' autobiographical memories. A study that examined memory for a political candidate's withdrawal from an election race found that older adults were more likely than younger adults to forget the intensity of their negative affect [39]. In another study, when asked to recall positive and negative events from their past and rate the characteristics of those memories, older adults indicated higher levels of positive feelings and less complexity associated with negative memories than younger adults did [40], consistent with previous findings that older adults use positive reappraisal as a strategy to cope with stressful encounters more often than younger adults do [41].

A greater focus on emotional goals when remembering also seems to influence the direction of distortion when people reconstruct past health and habits. Among several hundred nuns who recalled health behaviors and daily habits from 14 years ago, the direction of memory distortion became more positive with age [42]. However, in another group that rated their current emotions every so often during the memory questionnaire, both older and

younger nuns put a positive spin on their past health and personal habits (Figure 4). Thus, as previously shown in the study of memory for choices [31], reminding younger adults to pay attention to their current emotional state can lead them to show the same positivity effect in memory as older adults. Conversely, in a condition in which participants were induced to focus on memory accuracy, both younger and older nuns showed a negative bias in their memories (Figure 4). Evidently, the goals that are most salient at the time of retrieval can influence the valence of memories for both younger and older adults, but when not explicitly focused on any goal, older adults are more likely than younger adults to engage in emotion regulation strategies during the retrieval process. This suggests that emotion-regulation goals are chronically activated among older adults, but only activated in certain contexts for younger adults (for discussions of chronic accessibility of goals, see [43,44]).

In this study of nuns [42], completing the autobiographical memory questionnaire improved mood for the older group and the 'emotion-focussed' group, but not for the younger control group or 'memory accuracy' group. Thus, remembering things in a positive light can be an effective emotion-regulation strategy. Such positivity biases in memory are likely to be an important factor contributing to the increase in positive affect seen with age. For example, in an study that sampled experiences from participants' lives, increases in positive affect across the lifespan were seen for social occasions that involved reminiscing, but there were no age differences for affect in the other social occasions [45].

A long-term benefit?

It is possible that these benefits resulting from positive memory biases might be only temporary. In fact, one interpretation of the results is that older adults' positivity effects reflect repression or denial that might impair health in the long run. However, research with people grieving the death of a spouse suggests that experiencing positive affect even in response to negative events is beneficial rather than harmful [46]. Bereaved spouses who experience some positive emotions while grieving immediately after the death are more likely to thrive in the following years than those who show more pronounced distress.

In summary, older adults show positivity biases in memory that manifest themselves in a variety of ways, including selectively remembering a higher proportion of positive stimuli and a lower proportion of negative stimuli than younger adults do [20,32,33], attributing remembered choice features to options in ways that should satisfy emotional goals [31], and reconstructing autobiographical memories so they seem more positive than they actually were [39,42]. These biases help improve the moods of older people [42,45] and can also be induced in younger adults by reminding them to focus on their emotions [31,42]. In the next section, we argue that cognitive control processes help create these positivity effects.

Effective emotion regulation requires cognitive control

As reviewed in the section on attention, older adults are more likely than younger adults to ignore negative information [19,20,24]. Goal-directed selective attention requires control processes, as do other types of emotion regulation strategies, such as situation selection, situation modification, attentional deployment, reappraisal, and response modulation [47]. Research with younger adults suggests that the anterior cingulate, medial prefrontal cortex and orbital/ventromedial frontal cortex play important roles in implementing these emotional control processes [48–50].

Although cognitive control declines with age [4,5], there are significant individual differences in the degree of decline [51]. This leads to the counterintuitive prediction that those older adults who show the most effects of age in terms of cognitive control should show the least effects of age in the valence of what they attend to and remember. Even if they are more focused on emotional goals than younger adults, the low-cognitive-control older adults will have difficulty implementing them. This hypothesis could help to explain why older adults who have sustained strokes or microvascular lesions in frontal brain regions and have impaired executive processes are prone to latelife onset of depression [52,53] that is not responsive to antidepressant medications [54–56].

In addition, older adults who perform poorly on tests of cognitive control are less likely than those who perform well to show positivity effects in memory (Mather and Knight, unpublished). Dividing attention during a picture slide show does not affect the valence of younger adults' later recall, but eliminates the positivity effect for older adults (Mather and Knight, unpublished), consistent with our hypothesis that emotional goals have higher priority and are more likely to be allocated cognitive resources among older adults than younger adults. These links between cognitive abilities and emotion regulation suggest that older adults who show the fewest signs of cognitive decline are the ones who will be most likely to show positivity effects that help regulate emotion.

The amygdala and aging

The amygdala is a region of the brain that responds to emotionally arousing information (especially negative, threatening information) and helps enhance the consolidation of memory for such information [57–60]. Thus, it is possible that age-related declines in the amygdala might account for some of the age differences in emotional attention and memory.

However, current evidence suggests that older adults' preferential ignoring and forgetting of negative stimuli is not the result of amygdala decline. Findings that, compared with younger adults, older adults show as much of an advantage in detecting and orienting to threatening information [22,24], and as much of a benefit in memory for arousing relative to non-arousing stimuli [32,36–38], suggest they have relatively well-maintained amygdala function (see Table 1). Neuroanatomical studies are mostly consistent with this possibility, as, compared with other brain regions, the volume of the amygdala shows relatively little decline in normal aging [14,61,62].

Instead of overall decline in the amygdala, there might be changes in what stimuli it is most likely to respond to with increasing age. Older adults show as much of an

Box 2. Questions for future research

- There are many types of cognitive control of emotion, ranging from selective attention to reappraisal [50]. There is evidence that older adults engage in selective attention to emotional stimuli [19,20,24] as well as in selection strategies socially [70]. But how likely are they to engage in other types of emotion control? Are older adults also more likely than younger adults to regulate emotions through reappraisal or suppression or are these strategies less effective in the old?
- Further work is needed to understand the interplay of biological and motivational factors in older adults' positivity effects. We have argued that it is the older adults with high-functioning cognitive control abilities (which is correlated with little prefrontal decline) who should be most likely to show positivity effects. But are there changes in the brain that contribute to the age differences in emotional attention and memory or would younger adults with limited time horizons show the same effects? There is some initial evidence that changes in time perspective can make younger adults emotional memories more like those of older adults [71].
- Does the greater focus on emotion regulation in older adults also affect their decision making [72]? For example, does their greater allocation of attention to positive features of choice options [20] mean they weight these features more heavily in making choices than younger adults do? If positivity effects are observed during the decision process, are they associated with poor quality decisions because negative material receives less attention [73], or could a positive framing of options result in better decision quality?

increase in amygdala activation when viewing positive pictures as younger adults do, but significantly less of an increase when viewing negative pictures [63]. While viewing negative faces, they show less amygdala activation but more anterior cingulate activation than younger adults [64,65]. Recent research with younger adults indicates that amygdala activation can be downregulated by emotional control processes implemented by other brain regions, especially the anterior cingulate, medial prefrontal cortex and orbital/ventromedial frontal cortex [49]. Thus, older adults might be using top-down control processes supported by prefrontal brain regions such as the anterior cingulate to downregulate amygdala responses to negative information.

Conclusion

Because of their power to affect mood, memories have a utility that goes beyond the information they convey (see, for example, [66]). Recent research suggests that older adults are motivated by their focus on emotional goals to encode information and subsequently remember it in ways that enhance their well-being. Furthermore, those older adults who are best able to engage cognitive control mechanisms are most likely to be successful at remembering information in emotionally gratifying ways. The body of research we have reviewed suggests that motivation – in particular motivation to regulate emotion states – plays an important role in cognitive aging. In particular, these findings highlight the importance of considering the dynamic interplay among biological and motivational changes in older adults' everyday attention and memory (see also Box 2).

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