Trends in Cognitive Sciences

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Review

The Neurobiology of Reduced Autobiographical Memory Specificity

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There has been a recent growth in investigations into the neural mechanisms underlying the problems recalling specific autobiographical events that are a core feature of emotional disorders. In this review we provide the first synthesis of this literature, taking into account brain as well as cognitive mechanisms. We suggest that these problems are driven by idiosyncratic activation in areas of the brain associated with assigning salience and self-relevance to emotional memories. Other areas associated with inhibiting distraction and constructing vivid memory representations are also important. Each of these mechanisms may work independently or in concert with one another. Importantly, this interaction between mechanisms may differ between diagnostic and demographic groups such that similar problems in specificity may be characterised by different mechanisms. Given this challenge, neuroimaging may prove useful in identifying patient-specific biomarkers for interventions.

Highlights

People with emotional disorders often have difficulty retrieving specific autobiographical memories.

This difficulty is explained by problems in brain regions involved in executive functioning, emotion regulation, and the (re-)experiencing of self-relevant and emotional information.

There are also differences between individuals as to which of these mechanisms explains the specific problem they experience.

Neuroscientific methods offer exciting opportunities to explore unanswered questions regarding culture and age differences in memory specificity.

The findings presented here offer novel suggestions for interventions which target these problems in people with emotional disorders.

Autobiographical Memory Specificity

Autobiographical memories (AMs), defined as memories for personally experienced past events, offer examples of who we are and of failures and successes to be avoided or replicated. Some people, however, exhibit difficulty recalling specific events from their past (e.g., an occasion where they ate dinner with friends). When asked to retrieve a memory related to a cue (e.g., friend), they might instead retrieve general information (e.g., the idea of what a friend is). This tendency for reduced autobiographical memory specificity (rAMS) is one of the core cognitive mechanisms associated with emotional disorders such as depression [1–6] (Box 1 and Figure 1). rAMS is also a cognitive mechanism for which targeted interventions exist, and its amelioration through these interventions has been found to lead to an improvement in disorder symptoms [7–10]. Neuroscience research has begun to elucidate the neurobiology of specific autobiographical memory retrieval and its role amongst clinical groups who have difficulty retrieving specific memories. We provide the first synthesis of this literature. This review examines what we know about the neurobiology of autobiographical memory and memory specificity in particular. We consider what this means for why rAMS occurs and its role in emotional disorders, contrasting this neuroscience evidence with cognitive models of rAMS. We also consider what these advances in neuroscience mean for interventions seeking to improve memory specificity or to treat emotional disorders.

The Biological Architecture of Autobiographical Memory

Researchers have identified a network of brain regions across the prefrontal cortex, medial temporal lobe (MTL), limbic system, and occipital lobe that is associated with the **retrieval** (see Glossary) and re-experiencing of AMs, irrespective of their specificity [11–13], but which might be differentially activated as a function of specificity (Figure 2, Key Figure). In particular, activity in lateral portions of the prefrontal cortex (PFC) has been associated with early semantic

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Box 1. Reduced Autobiographical Memory Specificity: Causes and Consequences

When compared to healthy controls, reduced autobiographical memory specificity (rAMS) has been found amongst people with diagnoses of major depressive disorder, bipolar disorder, posttraumatic stress disorder, acute stress disorder, obsessive compulsive disorder, borderline personality disorder (for reviews see [3–5,80]), as well as anorexia nervosa [81,82] and schizophrenia [48]. Systematic reviews and meta-analyses have shown that, from a cognitive perspective, problematic repetitive thinking or rumination about the self, impaired executive functioning (e.g., impaired working memory, inhibitory control, verbal fluency), and a tendency to avoid negative affect (so called, functional avoidance) are each uniquely, and in combination, causally associated with rAMS because of the way they interfere with the retrieval of episodic memories from long-term store [3,83]. In turn, rAMS has been found to lead to the further exacerbation of these causal processes, as well as problems in aspects of life that involve using specific memories to inform our present behaviour or future plans. More specifically, rAMS has been associated with increased feelings of hopelessness regarding one's future [84,85], impaired ability to use past experiences in order to select solutions for problems one encounters [84,86–88], or to use these experiences to regulate our emotions [89]. rAMS, and in particular the extent to which we are able to communicate about our autobiographical experiences to others, may also have an important impact on our relationships with other people and the extent to which they support us in our lives [90]. Through these intervening processes, rAMS comes to be associated with emotional disorders (see Figure 1 in main text).

Glossary

Construction: the early process by which information is retrieved from store and pieced together to form a coherent memory representation.
Elaboration: the later process by which additional information and detail related to a memory is retrieved and added to that which had already been retrieved.
General memory: a memory for an event that occurred across a period of time longer than 24 hours (also referred to as an extended memory; e.g., I took my dog with me during my time at university) or which occurred on several occasions (e.g., when I walk my dog).
Retrieval: the process of (re-) accessing information from one's past.
Specific memory: a memory for an event that occurred at a discrete time and location and which lasted for less than 24 hours (e.g., I walked my dog last Tuesday).

processing and selective and controlled retrieval of memories from store. Activity in the ventrolateral PFC ensures that only cue-relevant information is retrieved, while the dorsolateral region is involved in elaborating upon this information in working memory and modifying it where necessary [14,15]. The detection and representation of the self-relevance of memories is then served by the medial PFC (mPFC) [13,16]. The amygdala, hippocampus, parahippocampal formation, and regions within the occipital lobe, including the cuneus and precuneus, have also been associated with re-experiencing of self-relevant, sensory, and emotional detail [17].

Disordered activity and connectivity across this network could therefore lead to problems with cue specification, holding information in working memory and monitoring and elaborating upon it, difficulty with self-referential processing, and/or diminished re-experiencing. During AM recall these mechanisms, in isolation or in combination, could contribute to problems retrieving

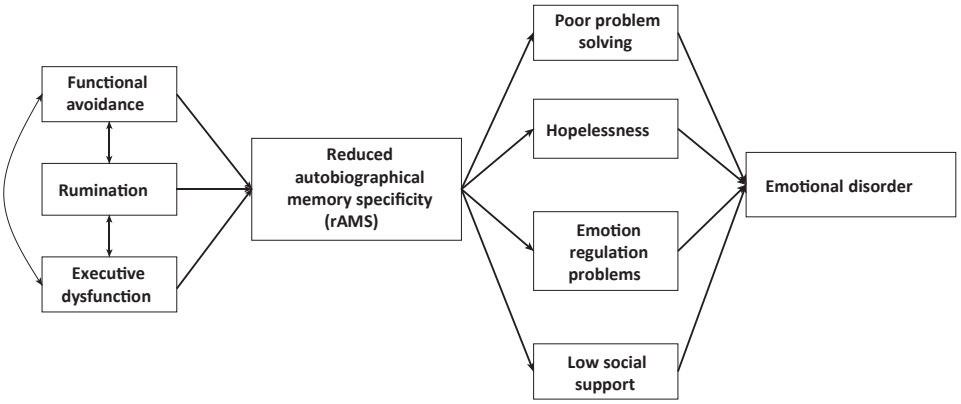

Figure 1. Reduced Autobiographical Memory Specificity Model. An outline of the mechanisms by which memory specificity comes to be compromised and the mechanisms through which memory comes to be associated with emotional disorder. Rumination, or repetitive thinking, about self-relevant semantically-related information, avoidance of negative emotions, and problematic executive functioning are supposed to compromise the search for a specific memory. Difficulty recalling specific memories then leads to impaired problem solving and emotion regulation, as well as a negative view of one's future and other negative social consequences. Through these mediating processes, reduced specificity causes and maintains the symptoms of emotional disorders.

Key Figure

Key Brain Regions Implicated in Specificity

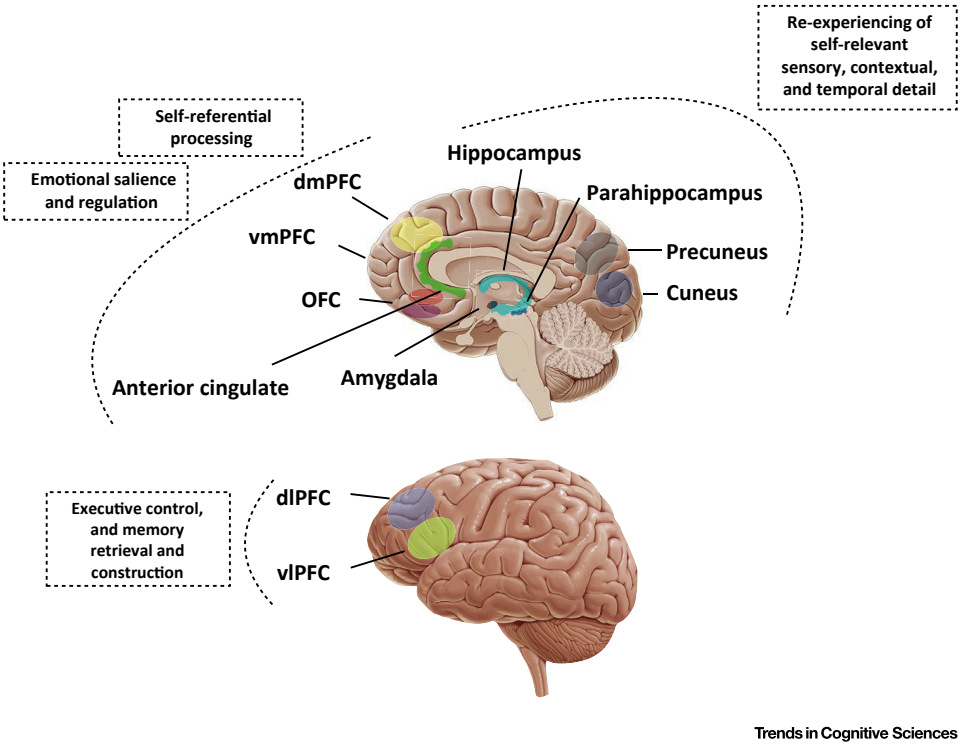

Figure 2. Agraphical depiction of key brain regions involved in the retrieval of specific autobiographical memories. Ventromedial (vm) and dorsomedial (dm) regions of the prefrontal cortex (PFC) as well as the orbitofrontal cortex (OFC), anterior cingulate, and amygdala play an important role in the processing of self-referential information and in assigning and regulating emotional salience. Temporal regions such as the hippocampus and parahippocampus, and occipital regions such as the cuneus and precuneus, also play an important role in the re-experiencing of the self-relevant sensory, contextual, and temporal details which characterise specific autobiographical memories. Finally, dorsolateral (dl) and ventrolateral (vl) PFC regions enable the controlled retrieval and construction of a memory whilst irrelevant thoughts and memories are inhibited.

specific memories. What then separates specific memories from non-specific memories in terms of how the brain retrieves them from store?

Specific Memory Retrieval

Models of AM retrieval suggest that when people retrieve specific AMs they first retrieve semantically-related information (e.g., the word 'happy' may evoke thoughts of one's daughter). Gradually more sensory-perceptual detail is then retrieved so that general or categorical memories are retrieved (e.g., spending time with one's daughter) followed by memories for specific events (e.g., when one rode a bike with one's daughter) [3,18,19]. A person's ability to progress through this process is then likely to be determined by neural processes involved in the **construction** of a **specific memory** from general information and which separates the

re-experiencing of a specific memory from the re-experiencing of other more general, semantic information.

Early investigations where participants listened to recordings of prior recollections of specific memories found that the mPFC and areas of the MTL showed dissociable activation when participants listened to personally relevant specific AMs relative to personally relevant general memories (e.g., autobiographical facts or repeated autobiographical events), non-personally relevant specific memories (e.g., memories for public events), or general knowledge [20–22]. These studies showed evidence that this activity, particularly within the hippocampus and amygdala, might be modulated by the strength of memory emotionality [21]. However, the nature of the listening aspect of these studies meant that these patterns of activation were likely to reflect reminiscence and **elaboration** on memories rather than retrieval and construction.

In subsequent studies participants recalled memories related to emotionally neutral words (e.g., chair) [23] or popular decade-old songs [24] whilst undergoing an fMRI scan (Box 2). Participants pressed a button when they retrieved a memory, indicating the end of a construction phase, after which participants had time to elaborate on the memory. The findings were largely in line with those of the previous investigations [20–22]: lateral and medial areas of the PFC and MTL were differentially recruited during specific, compared with general, AM construction. Similar patterns of activity to when participants retrieve a specific versus **general memory** are also evident when memories are cued directly (e.g., losing your dog at the pond), relative to when memories are cued by a word (e.g., dog), where, for the latter, greater efforts to construct a memory are required [25]. In an electroencephalograph (EEG) investigation, similar patterns of frontal and central activity during early construction of specific versus general memories were also found [26].

Box 2. Neuroimaging Methods and Specificity

Several paradigms have been utilised (i) to elicit specific versus general autobiographical memories; and (ii) to quantify individual differences in autobiographical memory specificity.

(i) As previous studies had presented participants with recordings of previously retrieved memories [22], subsequent investigations [23,24] gave participants cue stimuli (e.g., words or sounds) in the scanner and asked them to silently retrieve and elaborate on the memories evoked by these cues for approximately 30 seconds. Once participants had retrieved a memory, and prior to elaboration, participants were instructed to press a button such that differences in neural activation during memory construction and elaboration between specific and general memories could be compared.

(ii) Other studies, mostly comparing clinical or at-risk groups with control participants, presented participants with 20 each of positive, negative, and neutral cue words in randomised order. Participants had 12 seconds to either press a button if they retrieved a specific memory (prior instruction was given regarding the definition of a specific memory) or wait until the time expired [30,33,41,59]. One study used 10 cue words of each valence [37] and another gave an additional 15 seconds to retrieve a memory and a further 5 seconds for elaboration, although only data from elaboration were analysed [28]. Activation during specific memory recall was then contrasted with activation during a non-autobiographical semantic knowledge example generation task, where participants were given categories (e.g., flowers) from which they had to generate exemplars (e.g., lily). One early study contrasted activation with a mental arithmetic task expected to elicit activation in key executive functioning regions [28].

Across these paradigms, participants rated the detail or specificity, and often also the valence of their memories. This typically occurred immediately after the memories were retrieved and in most designs participants had approximately 10 seconds to make these estimates (c.f., [30]). Some investigations interviewed participants and asked them to report the memories they had retrieved verbally so that they could be coded by an experimenter (c.f., [33]).

Important differences in the patterns of activity between the construction and elaboration phases have also been reported. When participants recalled specific memories, areas of the brain, such as the lateral PFC, involved in early search processes and executive functioning [14,15] were most active during construction, with a decrease in activity as memories were elaborated on [23]. When participants recalled general memories, there was no decrease in activity over time. It is possible that once a specific AM is retrieved the search ceases and activity involved in this initial search decreases; otherwise, the search for a specific memory continues and, so too, the corresponding brain activity [23]. Indeed, when people recall memories which increase in specificity across time, this recall is associated with similar increases in dorsolateral and dorsomedial PFC activity over time as the search continues [24].

Specific AM construction, relative to elaboration, also preferentially recruited areas of the MTL that are involved in semantic processing and the representation of sensory-perceptual detail [23]. However, some of these regions also showed increases in activity from the construction to the elaboration phase when participants recalled general AMs. If one is unable to retrieve a specific memory, then activity in these areas of the MTL might reflect repetitive thinking about semantic information.

The construction and elaboration of specific memories is therefore associated with preferential recruitment of aspects of the brain involved in executive functioning and the retrieval and re-experiencing of self-relevant sensory, contextual, and temporal detail. This is in line with cognitive models of AMS that suggest that individual differences in specificity are characterised by differences in self-referential processing, which is the experience and regulation of emotions, and executive functions such as one's ability to hold information in working memory and inhibit distraction (Box 1) [27]. To what extent can rAMS amongst people with emotional disorders therefore be explained by abnormal patterns of activity in these regions?

Reduced Specificity and Emotional Disorders

Depressive Disorders

During retrieval of specific memories, people who are currently depressed, compared to healthy participants with and without a first-degree family member with major depressive disorder (MDD), as well as people remitted from MDD, have shown enhanced activation in aspects of the brain involved in the processing of emotional salience (e.g., insula, the pregenual anterior cingulate cortex, lateral orbitofrontal cortex), re-experiencing (e.g., parahippocampus/hippocampus), self-referential processing (e.g., medial frontal gyrus, precuneus), and also abnormal patterns of activity in areas of the prefrontal cortex associated with cue specification, executive functioning, and emotion regulation (e.g., dmPFC, dlPFC) [28–35]. The extent to which participants with depression can recruit these regions during recall is correlated with the specificity of their recall [36]. This pattern of activation during recall of specific memories may therefore be indicative of compensatory functioning whereby people with depression work harder than healthy controls to retrieve specific memories.

Volumetric analyses also suggest that amongst people with depression, lower grey matter volumes in the hippocampus and precuneus are both associated with reduced recall of specific memories [37]. Aberrant resting-state functional connectivity in the precuneus has also been found to correlate with worse specificity amongst people with MDD [38]. These effects may be attributable to differences between people with depression and healthy controls in the blood levels of neuroprotective molecules such as kynurenic acid (KynA), which regulate NMDA receptor proliferation in key brain regions such as the hippocampus [31].

Studies have also examined valence-specific effects and found evidence that for participants with depression, specific memories cued by positive words may elicit weaker activity in areas of the brain associated with emotional salience and arousal (e.g., insula), self-referential processing (e.g., precuneus) and increased activity in executive functioning regions (e.g., lateral PFC) [33,39,40]. Conversely, specific memories cued by negative words may elicit stronger activity in areas of the brain associated with focusing one's attention on others (e.g., superior temporal gyrus) and increased activity in areas of the brain associated with emotional salience [33,39]. Functional connectivity analyses have also shown valence-specific effects such that impaired recall of positive specific AMs has been associated with higher self- and clinician-rated depression severity and reduced connectivity between the amygdala and other regions associated with salience processing [41]. Conversely, greater functional connectivity amongst people with, relative to people without, depression has been found between the amygdala and areas of the brain involved in salience (e.g., dorsal anterior cingulate and insula) and self-relevance (e.g., precuneus) processing during recall of negative specific memories [41]. For people with depression, positive specific memories may be less salient than negative specific memories, which may influence the accessibility of these memories. Indeed, enhancing amygdala activity in the presence of positive memories through real-time fMRI neurofeedback has been associated with improvements in specific memory recall [42].

rAMS within depressive disorders therefore seems to be driven by problematic activation within and between areas of the brain associated with assigning salience and self-relevance to emotional stimuli and other areas associated with executive functioning, as well as constructing and holding in mind emotionally vivid memory representations.

Other Diagnostic Groups

There are comparatively fewer studies examining the neural basis for rAMS in other diagnostic groups. A similar association between reduced hippocampal volume (particularly in the left hemisphere) and rAMS as is evident in depression has also been found amongst patients with schizophrenia [43,44]. Also, relative to healthy controls, during autobiographical memory retrieval male patients with schizophrenia showed lower activity across the same network of brain regions previously implicated in specific memory retrieval (e.g., anterior cingulate, precuneus, lPFC, and areas in the MTL and occipital lobe) [45]. Similar findings are also evident amongst people with posttraumatic stress disorder (PTSD) [46,47]. These patterns of activation were recorded during the retrieval of memories, irrespective of their specificity, whereas other studies in depression report only the patterns of activation during retrieval of specific memories. As such, lower activity in the observed regions in these studies is likely to explain why patients have difficulty recalling specific memories [48] rather than exemplifying the additional effort that is required to recall a specific memory, or the detail and vividness of these memories once retrieved, as in studies in depression [33,39,41]. Nevertheless, in studies conducted with people diagnosed with PTSD, participants elicited a pattern of activation within and between the mPFC, amygdala, and OFC that suggests that they may experience negative memories as more vivid and self-relevant than healthy controls, who instead exhibit the same pattern of activation during retrieval of positive memories [46,47].

Comparisons of participants with bipolar disorder (BD) or MDD to healthy controls have found that people with BD and MDD recall significantly fewer specific memories than healthy controls but do not differ significantly from one another [32]. However, people with BD show a pattern of activity during specific memory recall that suggests these memories have enhanced salience and emotional vividness and that they are processed as more self-relevant relative to patients with MDD and healthy controls [32,49]. Some of these effects may also be valence-specific

such that positive memories are processed as particularly self-relevant, perhaps reflecting the manic nature of BD. Whereas, negative specific memories may be less salient for patients with BD than patients with MDD, but might also be more salient for BD patients than for healthy controls [32,49].

Although the same regions of the brain are implicated in reduced specificity amongst people with BD and MDD, these findings suggest that different patterns of neural activity might underlie their impaired recall.

Gender Differences

Similar differences in neural activity despite comparable recall performance are also evident when comparing men and women. Studies have consistently shown differences between men and women in the activation of the hippocampus/parahippocampus and dlPFC when recalling positive and negative specific AMs [30,33,50,51]. Enhanced parahippocampal/hippocampal activity that is observed amongst men, relative to women, may be due to enhanced re-experiencing of visuospatial-contextual detail amongst men compared to the kind of re-experiencing that women engage in [51]. Conversely, greater utilisation of the lateral and medial PFC amongst women relative to men may reflect attempts amongst women to exert cognitive control over the emotional responses evoked by specific memories [30].

Gender effects may also interact with depression status. In particular, women show a pattern of activation in the mPFC that suggests that, relative to men, they may find positive specific memories less self-relevant and negative specific memories more self-relevant. And yet, depressed women exhibit a pattern of activation that suggests they may find positive AMs even less self-relevant and negative memories even more self-relevant than healthy women [33].

At-Risk and Resilient Groups

Again, studies have shown that at-risk groups do not typically differ from people with current depression in terms of their recall performance and yet, although there are some similarities between these groups in the neurobiology of their recall, there are also some important differences. People at high familial risk for depression [33] and also people who have had breast cancer and are therefore at risk of developing emotional disorders [52] have shown a similar correlation between lower hippocampal volume and lower specificity, as is evident amongst people who are depressed. However, people in remission or at high familial risk of depression also show a pattern of activity indicating that they may experience more difficulty retrieving and re-experiencing specific memories than healthy controls (e.g., impoverished activity in dmPFC and parahippocampus/hippocampus) but that this is enhanced relative to people who are depressed [29,34].

There are also valence-specific effects. People in remission and people at high familial risk show similarly enhanced amygdala activity as people who are depressed during recall of negative specific memories relative to healthy controls. And yet, they also show enhanced activity relative to people who are depressed when recalling positive specific memories [41]. Similar patterns of amygdala activity have also been found amongst people exposed to maltreatment when compared to people without exposure [53]. Amygdala hyperactivity in the presence of negative information may be a trait-like marker for emotional disorders that is present even in the absence of a current disorder, whereas amygdala hypoactivity in the presence of positive specific memories may instead be a marker for a current disorder [54–58].

People at familial risk for depression and people in remission from depression are also distinguishable from one another. In particular, people at high familial risk have shown enhanced activity in executive functioning and cognitive emotion regulation regions (e.g., vlPFC, dmPFC, and lateral orbitofrontal cortex) relative to healthy controls and remitted depressed patients when recalling specific memories [59]. Here too there may be valence-specific effects such that people with a familial risk for depression may experience positive specific memories as more self-relevant and negative specific memories as less self-relevant than remitted patients [59]. Similar findings are evident amongst the adult offspring of postnatally depressed (PND) mothers. When these people recall specific positive childhood situations, they have shown enhanced activity in the precuneus and posterior cingulate relative to the offspring of non-depressed mothers [60]. It is important to note that, in these studies, participants at familial risk and the offspring of PND mothers were already in adulthood, suggesting that they may instead represent a resilient group who have not developed depression despite their risk. This activity might therefore reflect the adaptive processing of self-relevance and their ability to utilise cognitive control mechanisms in order to retrieve specific memories and to downregulate their emotions during retrieval.

In summary, despite similar behavioural performance, people at risk of emotional disorders have shown patterns of activity that suggest they may have greater difficulty retrieving specific memories than healthy controls but similar or enhanced retrieval abilities relative to depressed patients. Within these groups there are important differences in the utilisation of cognitive emotion regulation strategies and self-relevance processing that might increase their resilience. However, the absence of longitudinal studies precludes such conclusions.

The Neuroendocrinology of Memory Specificity

Given the importance of glucocorticoids in key brain regions implicated in the broader symptomatology of depression [61] and also AMS (e.g., PFC and hippocampus) several studies manipulated cortisol levels to examine if this would lead to changes in memory specificity. These studies have shown that the administration of hydrocortisone, relative to a placebo, leads to significantly lower specificity amongst healthy participants, particularly for memories cued by neutral words (10 mg oral [62,63]; 0.45 mg/kg intravenous [64]). Similar findings are evident in studies involving an acute psychosocial stressor where increases in salivary cortisol levels from baseline correlated with reduced specificity for recent memories (<2 years old) [65]. However, other hydrocortisone studies [66,67] with larger samples failed to replicate these effects (N = 22 [62]; N = 16 [63]; N = 54 [66]; N = 65 [67]).

Amongst depressed patients, neither elevated basal cortisol levels [68] nor increases in cortisol levels following hydrocortisone [63] have been associated with reduced specificity relative to participants with lower basal cortisol levels or participants given a placebo. By contrast, another investigation amongst patients with PTSD found that patients who were given hydrocortisone (10 mg) showed comparable levels of specificity relative to healthy controls given a placebo and significantly greater specificity than other patients with PTSD given a placebo [67]. These differential effects may be explained by differences in basal cortisol between different groups and also between people within a diagnostic group, as well as individual differences in the reception of cortisol within the brain, particularly in areas of the brain such as the hippocampus [37]. Indeed, administration of a glucocorticoid receptor antagonist to healthy participants, thereby reducing the occupation of these receptors by cortisol, has been found to lead to significant improvements in specificity relative to a placebo [69]. No study has yet examined the neural mechanism by which cortisol influences specific memory retrieval. However, the density

of glucocorticoid receptors in the prefrontal and hippocampal regions suggests that cortisol levels might influence these brain regions during the retrieval process [63].

Other hormones, for instance oxytocin, are also likely to play a role in autobiographical memory retrieval [70]. In one study to examine this association, intranasal administration of oxytocin was associated with enhanced AMS compared with a placebo [71]. These effects may be due to the dampening effect of oxytocin on cortisol levels [72], however, this suggestion has yet to be tested.

These findings suggest that acute stress might impact the retrieval of specific memories through its effects on cortisol. Also, chronic abnormalities in cortisol secretion and reception may contribute towards the reduced specificity that is seen in clinical groups. There is a need for more research into the role of hormones in AMS.

Recommendations for the Future

The evidence to date supports the suggestions of cognitive models [3,19] that reduced memory specificity within emotional disorders is associated with capture by and repetitive thinking about self-relevant information, impoverished executive functioning, and problematic emotion regulation (Box 1). Notably, however, neurobiological studies comparing clinical participants with healthy controls are mostly confined to depressive disorders. Also, they mostly involve an examination of between-group differences in activity when specific memories are being retrieved, rather than a comparison of activity during the retrieval of specific versus general memories or an examination of group differences in the time-course of activity.

Although studies in other diagnostic groups are warranted, our review suggests that even though similar neural structures may play a role in rAMS in other diagnostic groups, the exact mechanisms which drive rAMS between groups are likely to differ. For example, bipolar disorder seems to be characterised by a unique pattern of processing for positive self-relevant information that is otherwise dampened in depression, and yet both groups show similar recall performance [32,49].

To examine questions like this in sufficient detail, several adaptations to current designs are needed. First, an analysis of general memory retrieval is needed so that we might delineate the kind of activity that is associated with failed attempts to retrieve a specific memory from the activity that is associated with successful retrieval. Second, if clinical participants can indicate when memory construction has ended and elaboration has started [23,24] then we might examine whether failure to retrieve specific memories in clinical groups is explained by capture by, and fixation on semantic or self-relevant information relative to when specific memories are retrieved. Many of the studies in this area have used brief retrieval periods (12 s; Box 2). It remains possible that between-group differences reflect differences in construction rather than memory elaboration. Third, studies might include additional neuroimaging or behavioural tasks to examine other cognitive mechanisms associated with rAMS such as executive functioning and their contribution to the neural activity underlying failures to retrieve specific memories. There is also a need for longitudinal investigations with at-risk and clinical groups to examine whether neural markers for rAMS can predict changes in disorder severity over time [1] or if they moderate responsiveness to interventions that target rAMS [7].

One interesting finding that has emerged through neuroscience investigations of AMS is that even when groups show similar levels of specificity (e.g., men and women or different diagnostic groups or high-risk versus remitted participants) their performance may be

explained by different patterns of neural activity. This is something that should be addressed by researchers who examine memory specificity using only behavioural measures. Even if people are similarly unable to recall a specific memory, how do we quantify the process by which each individual failed in this recall? On the basis of the neurobiological evidence presented here, a move away from group-level analyses where we suggest that one mechanism or another explains rAMS is warranted. Research should focus on analysing person-level variability and how some mechanisms might explain rAMS amongst some people but not others. Such findings also have important implications for interventions for emotional disorders and also those which target memory specificity. Catch-all interventions which are not personalised to specific mechanisms within a given person are unlikely to meet the needs of all individuals, as the same observable behaviour may be underpinned by different mechanisms. For example, interventions might target self-relevance of negative memories as well as executive dysfunction [73,74].

Finally, neuroimaging offers us the opportunity to answer questions not otherwise answerable with behavioural examinations. Research suggests that there are important differences between cultures in the extent to which they are able to retrieve and report specific memories [75–78] and the same is true for young and old people [79]. As behavioural assessments of memory specificity may be confounded by linguistic or sociocultural differences, such factors may influence the reporting of specific memories between cultures or age groups, even if they are retrieved to equal extent covertly. Research should examine whether cultural and age-related differences in specificity are attributable to similar differences in underlying neurobiology during retrieval.

Concluding Remarks

Although there are several important outstanding questions, the evidence presented here accords with cognitive accounts of rAMS. People with or at risk of emotional disorders have difficulty retrieving specific autobiographical memories because of impoverished executive functioning and the cognitive regulation of emotions, as well as problematic processing of self-relevance and assigning appropriate salience to emotionally-relevant information. Though two people may experience similar problems with specificity, these problems may be explained by very different neurocognitive mechanisms. Future research must examine these person-level factors in greater detail in order to advance our understanding of rAMS and develop novel interventions for targeting rAMS and treating or preventing emotional disorders.

Outstanding Questions

Do clinical participants differ from controls in the construction versus elaboration of specific and general memories? Studies with healthy participants have separated the activation that underlies memory construction and elaboration. No study has yet examined whether clinical and control groups differ in these processes.

How do different clinical groups compare to one another? Existing case–control neuroimaging comparisons are mostly confined to depressed patients. It would be interesting to see not only how different diagnostic groups compare to healthy controls, but also how different diagnostic groups compare to one another even if they show similar problems with specificity measured behaviourally.

Are there neural markers that precede the emergence of reduced specificity and which predict changes in clinical symptomatology?

Do psychotherapeutic interventions which improve memory specificity, such as Memory Specificity Training (MeST), also alter the neural underpinnings of specificity?

Are cultural and age-related differences in specificity attributable to similar between-group differences in the underlying neurobiology of memory retrieval?

Do memory specificity and detail rely on different neural processes? Recent investigations suggest that memory specificity and detail are differentially associated with depression. Future research should examine whether these differences are because specificity and detail rely on distinct neural processes.

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