Invited essay

A cognitive neuroscience account of posttraumatic stress disorder and its treatment

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Abstract

Recent research in the areas of animal conditioning, the neural systems underlying emotion and memory, and the effect of fear on these systems is reviewed. This evidence points to an important distinction between hippocampally-dependent and non-hippocampally-dependent forms of memory that are differentially affected by extreme stress. The cognitive science perspective is related to a recent model of posttraumatic stress disorder, dual representation theory, that also posits separate memory systems underlying vivid reexperiencing versus ordinary autobiographical memories of trauma. This view is compared with other accounts in the literature of traumatic memory processes in PTSD, and the contrasting implications for therapy are discussed. © 2001 Elsevier Science Ltd. All rights reserved.

Posttraumatic stress disorder (PTSD) is a disorder that after many years of neglect is coming under intense research scrutiny. At present a variety of psychological models have been put forward that address different features of the disorder (e.g. Brewin, Dalgleish & Joseph, 1996; Chemtob, Roitblat, Hamada, Carlson & Twentyman, 1988; Creamer, Burgess & Pattison, 1992; Ehlers & Clark, 2000; Foa, Steketee & Rothbaum, 1989; Litz & Keane, 1989). All of the models account well for some aspects of the disorder, and it is difficult to discriminate between them purely on the basis of psychological observations. Increasingly, it is being recognised that it may be helpful to test the plausibility of models by examining data from a variety of sources and to develop more integrative accounts that draw on both biological and psychological knowledge (e.g. Bremner, Krystal, Southwick & Charney, 1995; Metcalfe & Jacobs, 1998; Pitman, Shaley & Orr, 2000; van der Kolk, 1996). In this article I describe some recent advances in cognitive science that may assist us in constructing a plausible model of PTSD. In particular, I address the likelihood that there are distinct types of memory that have different neural bases, behave in different ways, account for different kinds of symptoms, and respond to different kinds of treatment.
1. Features of PTSD requiring explanation

What distinguishes the type of response to trauma that we label as PTSD? Among the most interesting features of PTSD are the disorganization and incompleteness of the trauma memory, the reexperiencing of the traumatic event in the form of spontaneous “flashbacks”, the time distortion typical of flashbacks, the unpredictable time course of intrusive memories connected with the trauma, and the sense of unreality that typically surrounds the traumatic event. We also know that many effective treatments for PTSD involve the reconstruction and repetition of a detailed oral or written trauma narrative (Resick, in press), but as yet we have little detailed understanding of why the production of such a narrative is so often therapeutic.

Disorganization in the trauma memory, indexed by gaps in recall and difficulty in producing a coherent narrative, is typical of normal trauma memories (e.g. Tromp, Koss, Figueredo & Tharan, 1995) and has been described by many PTSD researchers, including Foa, Molnar and Cashman (1995), Harvey and Bryant (1999) and Janet (1904). This disorganization may partially explain the tendency for PTSD patients in psychotherapy to progressively recall additional details of their traumatic experience, such that they produce longer narratives at the end than at the beginning of therapy (Foa et al., 1995). However, the structure of trauma narratives in PTSD patients is complex. Typically, they involve periods of strategic recall as the person effortfully reconstructs the sequence of events. These are usually interspersed with periods of intense distress (sometimes referred to as ‘hot spots’) during which the person spontaneously relives specific moments of the event in the form of a ‘flashback’ (Ehlers & Clark, 2000; Hellawell & Brewin, 2000a,b). Reliving may be momentary or last for periods of minutes or (exceptionally) hours. During these moments a variety of dissociative responses have been described, including emotional numbness, depersonalization, derealization, and spontaneous switches from using the past to using the present tense (Pillemer, 1998; Reynolds & Brewin, 1999). The occurrence of dissociative responses is related to higher levels of fragmentation in the trauma narrative (Murray, Ehlers & Mayou, 2000).

Reexperiencing of trauma in the form of flashbacks appears to be different from ordinary autobiographical memory in a number of ways. Flashbacks occur spontaneously, being triggered automatically by internal or external cues, and are only under limited strategic control (Brewin et al., 1996). That is, PTSD patients cannot exercise complete control over the occurrence or non-occurrence of flashbacks, but can only attempt to manipulate the probability of them being automatically triggered, e.g. by approaching or avoiding salient trauma-related cues. Flashbacks contain more prominent perceptual features than ordinary memories, and are often described as being exceptionally clear and vivid (e.g. van der Kolk & Fisler, 1995). This vividness stands in contrast to traumatic recall in the normal population, where investigators have found memories that are vague and unclear relative to those of non-traumatic events (e.g. Tromp et al., 1995).

Flashbacks also differ in being experienced as though the event were happening again in the present, thus involving a distortion of subjective time (Janet, 1904; Bremner et al., 1995). Patients often report reexperiencing traumatic moments as they simultaneously interact with their therapist in real time. During these periods there is a drain on cognitive capacity that may result in reduced engagement with the current environment. Flashbacks appear to reflect a self-contained form of memory that does not necessarily interact with general autobiographical knowledge. For example,
PTSD patients can reexperience being assaulted by a mugger in the present even though they know their attacker is at that moment in prison.

Horowitz (1986) noted that PTSD involves phases of intrusion and avoidance of unwanted memories. The occurrence of delayed onset PTSD, in which memories do not begin to intrude until months or years after the trauma, was recognised in the DSM-IIIR (American Psychiatric Association, 1987). Another interesting feature of PTSD is the tendency for trauma to shatter long-held assumptions (Janoff-Bulman, 1992), with many patients finding a consequent difficulty in accepting the reality that the event has occurred. Resick and Schnicke (1993) described the existence of two forms of common post-trauma cognitive distortion, one in which the reality of the event is distorted or minimized (overassimilation), the other in which the person magnifies the implications of the event so that, for example, threat is perceived to be universal (overaccommodation).

2. Dual representation theory

In order to explain these phenomena a cognitive theory based on multiple memory systems was proposed by Brewin et al. (1996). According to their dual representation theory, memories of a personally experienced traumatic event can be of two distinct types, stored in different representational formats. One type of format (“verbally accessible memory” or VAM) supports ordinary autobiographical memories that can be retrieved either automatically or using deliberate, strategic processes. VAM memories can be edited and interact with the rest of the autobiographical knowledge base, so that the trauma is represented within a complete personal context comprising past, present, and future. They contain information that the individual has attended to before, during, and after the traumatic event, and that received sufficient conscious processing to be transferred to a long-term memory store in a form that can later be deliberately retrieved. These memories are therefore readily available for verbal communication with others, but the amount of information they contain is restricted because they are mediated by limited-capacity serial processes such as attention. Attention span is known to be adversely affected by high levels of arousal, further restricting the volume of information that can be registered during the traumatic event itself. The emotions that accompany VAM memories involve cognitive appraisals occurring both during the trauma and also after the trauma, as the person considers the consequences and implications of the event.

The second type of format (“situationally accessible memory” or SAM) supports the specific trauma-related dreams and ‘flashbacks’ that are a particularly notable feature of PTSD. Dual representation theory proposes that the SAM system contains information that has been obtained from more extensive, lower level perceptual processing of the traumatic scene (e.g. visuospatial information that has received little conscious processing) and of the person’s bodily (e.g. autonomic, motor) response to it. This results in flashbacks being more detailed and affect-laden than ordinary memories. Because the SAM system does not use a verbal code these memories are difficult to communicate to others and do not necessarily interact with other autobiographical knowledge. SAM memories can be difficult to control because people cannot always regulate their exposure to sights, sounds, smells etc. that act as reminders of the trauma. The emotions that accompany SAM memories are restricted to those that were experienced during the trauma.
or subsequent moments of intense arousal. They primarily consist of fear, helplessness, and horror but may less often include concurrent emotional states such as shame (Grey, Holmes & Brewin, 2000).

Although dual representation theory is consistent with clinical observations it has as yet received limited empirical evaluation. In a recent study (Hellawell & Brewin, 2000a,b) individuals with PTSD wrote a detailed trauma narrative and subsequently identified those sections of the narrative that were written while they were experiencing a flashback. The data confirmed that, compared to ordinary memory sections, flashback sections were associated with more use of perceptual words such as ‘see’ and ‘red’ and more mention of fear, helplessness, and horror. Moreover, during flashback there was more interference with a concurrent visuospatial task, supporting the hypothesis that reliving experiences are based on lower-level, perceptual processing of events. At this early stage it is therefore important to establish whether the theory is consistent with recent advances in cognitive neuroscience, and in particular with what is known about the neural basis of memory for fear.

3. Cognitive neuroscience and fear

Much of our understanding of the brain mechanisms involved in the response to extreme fear comes from studies of conditioning. One important set of findings concerns the durability of fear conditioning. Consistent with observations about the frequent return of fear after successful psychotherapy (Rachman, 1989), it has been found that fear responses in animals can be easily reinstated following successful extinction, for example by placing the animal into a different context (Bouton & Swartzentruber, 1991; Jacobs & Nadel, 1985). The implication is that during extinction/habituation the original memories of the fearful experience are not altered by the incorporation of incompatible information, as was for example suggested in an influential article by Foa and Kozak (1986). Rather, overcoming fear involves acquiring completely new representations which can under certain conditions inhibit activation of the original intact memories. As proposed by various authors (e.g. Bouton, 1994; Brewin, 1989), the person or animal learns in some new context that the conditioned stimuli no longer signal threat, and creates new memories corresponding to this experience.

Generalization of this new learning then depends on whether a test situation elicits the original fear memory or the new memories created in therapy. This in turn is likely to depend on the relative accessibility of the memories, and on the number of features the test situation has in common with both sets of memories. For example, a person who has been repeatedly humiliated in childhood and finds it very difficult to stand up for himself as an adult may be systematically trained to be assertive in a variety of social situations. This new learning is likely to remain highly accessible so long as he continues to be assertive after therapy has ended, and does not encounter individuals whose perceptual features are too similar to those of the people who originally humiliated him. Unexpected encounters with such individuals, who may have a very similar facial expression or tone of voice, or use similar phrases, are likely to lead to the spontaneous return of fear.

Studies of the neuroanatomy of brain systems controlling fear responses throw further light on these processes. A key structure is the amygdala, which is responsible for initiating a variety of
hard-wired responses to threat including release of stress hormones, activation of the sympathetic nervous system, and behavioural responses such as fight/flight and freezing (LeDoux, Iwata, Cicchetti & Reis, 1988). Information about threat is conveyed from the sense organs to the amygdala via a number of separate pathways (e.g. Armony & LeDoux, 1997; LeDoux, 1998). Studies with rats suggest that there are rapid subcortical pathways via the thalamus that involve very few synapses. Relevant information about the stimuli signalling threat, processed mainly at the level of individual perceptual features, can reach the amygdala and activate defensive responses extremely quickly. The other pathways involve a series of cortical structures including unimodal sensory cortex, association cortex, and the hippocampus, all of which project independently to the amygdala. These pathways involve more synapses and are slower, but they permit increasingly more sophisticated processing of information. For example, some pathways transmit information about whole objects in the visual field rather than individual perceptual features. A strong case has been made that the hippocampus is involved in learning about the context in which fear was conditioned. Thus, lesions of the hippocampus disrupt learning about context but appear to leave simple acquisition of conditioned fear intact.

In contrast to the acquisition of fear, in which cortical structures do not appear to be essential, lesion studies with rats have demonstrated that the projection from the prefrontal cortex to the amygdala is needed for extinction to occur (e.g. Armony & LeDoux, 1997). Pathways from the prefrontal cortex can thus exercise both facilitatory and inhibitory control over the amygdala. This enables fear responses to be increased or decreased in line with the revaluation of threatening stimuli as new information is acquired (see Davey, 1993). The hippocampus also appears to have an important role in the extinction of conditioned fear (Douglas, 1972; McCormick & Thompson, 1982). One suggestion is that extinction is mediated by the formation of inhibitory associations in the hippocampus (Benoit, Davidson, Chan, Trigilio & Jarrard, 1999). The hippocampus may exercise inhibitory control over the amygdala either through the direct connections between the two structures or, more likely, via the projection of the hippocampus to prefrontal cortex.

These neuroanatomical data suggest mechanisms that could explain the durability of fear conditioning and the return of fear. As proposed by Ledoux and colleagues, among others, the acquisition of fear can be mediated both by subcortical and by a variety of higher-level cortical pathways. Extinction, on the other hand, is mediated exclusively by cortical pathways, with the central involvement of the hippocampus. Projections from the hippocampus and from prefrontal cortex have the capacity to inhibit the activation of the amygdala in contexts associated with safety, but in unfamiliar contexts where there are no safety cues or in contexts associated with threat no inhibition takes place and the original fear response is reinstated. Moreover, the return of fear may be in response to low-level perceptual features of the original learning situation, such as movement of an object at a particular speed and in a particular direction (see Hellawell & Brewin, 2000b; Riskind, 1997), that received little conscious processing and that do not figure in a verbally accessible memory.

4. Cognitive neuroscience and memory

For the purposes of this article the distinction between declarative and nondeclarative, or explicit and implicit, forms of memory is important to bear in mind even though it does not map...
Declarative memory involves representations of facts and events that are subject to conscious recollection, verbal reflection, and explicit expression (Eichenbaum, 1997; Squire, 1994). A prime example is autobiographical memory. Declarative memory is supported by a complex of structures involving the medial temporal lobe and hippocampus. During encoding and retrieval these structures interact with prefrontal cortex, an area variously thought to be the site of executive control, a working self system, or the capacity to be aware of one’s protracted existence across subjective time (Conway & Pleydell-Pearce, 2000; Wheeler, Stuss & Tulving, 1997). As applied to memory one function of executive control is to inhibit the entry of unwanted or irrelevant material into consciousness, with the help of mechanisms such as retrieval inhibition and post-retrieval decision processes (Bjork, 1989; Brewin & Andrews, 1998; Johnson, 1994). Such inhibitory processes are typically regarded as an essential element in efficient cognitive functioning, to require attentional resources, and to have the potential to be disrupted by competing tasks, emotions, or goals (e.g. Conway & Engle, 1994; Hasher & Zacks, 1988; Wegner & Wenzlaff, 1996).

Within the declarative memory system the hippocampus appears to be specialised for the learning of context (including temporal context: Kesner, 1998) and for learning relational properties among stimuli. It is thought to be crucial in “binding” together the separate elements of an episode to make a coherent and integrated ensemble. Eichenbaum (1997) proposed that the hippocampus encodes separate stimulus elements and the relations between them such that the representations can be utilised flexibly and accessed in a variety of ways. It has also been suggested that the hippocampus is the structure particularly associated with memories of conscious experience (Moscovitch, 1995).

One prominent view is that the hippocampus is not a permanent repository for declarative memories, since damage to this region interferes with new learning but leaves remote memory intact, and that long-lasting memories are consolidated elsewhere in the cortex (e.g. Squire & Alvarez, 1995; but see Nadel & Moscovitch, 1997, for an alternative position). McClelland, McNaughton and O’Reilly (1995) proposed that the hippocampus is a rapid learning system that can respond to momentarily changing circumstances, distinct from a neocortical memory system that provides for longer-term storage and that learns slowly about the underlying structure present in ensembles of similar experiences. The representation of an experience in the neocortical system depends on a widely distributed pattern of neural activity. The repeated reinstatement of hippocampally-based memories, for example through rehearsal, permits the neocortex to learn by making a series of small adjustments to the connections between neurones.

In accounting for the existence of these different types of memory system, McClelland et al. (1995) point out that the neocortical system, although efficient at gradually extracting underlying rules and consistencies, is unable to respond rapidly to new information that contradicts what has already been learned. Such information tends to produce “catastrophic interference” (McCloskey & Cohen, 1989), with the network being unable to integrate the new data and responding by ignoring relevant past experiences. The existence of a hippocampal system, however, may permit the rapid formation of representations of the new information in a way that avoids interference with the knowledge already available in the neocortical system. McClelland et al. propose that the most efficient way of allowing the neocortical system to integrate the new information is via a process they call “interleaved learning”, in which the system is gradually exposed to the new information interleaved with old examples from the same domain. This process
enables the network to be slowly reorganised so that it can successfully incorporate both old and new facts in an integrated way.

Nondeclarative memory is thought to be expressed in a wide variety of phenomena, such as the acquisition of motor and cognitive skills, priming, and conditioning. It is usually characterised by its inaccessibility to deliberate, conscious recall, being automatically elicited under conditions that bear a strong similarity to the conditions of the original learning. Typically this involves “hyperspecificity of access”, a term meaning that memories are elicited in a rather inflexible way by highly specific cues. Nondeclarative memory tends to be expressed through implicit measures of performance, such as an increase in speed or a shift in choice bias during repetition of a mental procedure (Eichenbaum, 1997). None of these expressions of memory are thought to be primarily mediated by the hippocampus, and there is some evidence for a double dissociation between memory systems underlying explicit and implicit memory (e.g. Gabrieli, Fleischman, Keane, Reminger & Morrell, 1995).

Tulving and Schacter (1990) proposed that some nondeclarative memory phenomena reflected the operation of a separate “perceptual representation system”. This system, they suggested, is concerned with the identification of perceptual objects and is not dependent on brain regions supporting episodic and semantic memory. It develops early and is differentially preserved later in life. For Tulving and Schacter, the products of the perceptual representation system do not provide a basis for conscious awareness of previous experience. However, other theorists have proposed memory systems that have similar qualities to the perceptual representation system but that could support some degree of conscious awareness (e.g. Johnson & Multhaup, 1992). Brown and Kulik (1977) suggested that “flashbulb memories”, vivid and long-lasting memories of the context in which someone learned of a momentous event such as the death of President Kennedy, were the product of a non-verbal, imaginal memory system which produced long-lasting records of consequential events. Pillemer (e.g. Pillemer, 1998) has consistently argued for dual verbal and imaginal memory systems, the former being under conscious control and the latter being an exclusively automatic memory system present from birth. According to Pillemer, the imaginal system produces an upswell of perceptual images as people recall highly emotional experiences. The relation of image-based memory to the declarative–nondeclarative distinction has received little attention to date.

5. The effects of fear on memory

From the foregoing review it may be inferred that the hippocampal processing of information about fear-evoking situations results in the laying down of integrated, coherent representations of conscious experience, located in the appropriate temporal and spatial context. These representations are available for deliberate recall. However, it is possible for information to reach the amygdala via a number of different routes, independently of the hippocampus. For example, the visual areas of the inferior temporal cortex, which are involved in the late stages of sensory processing, project strongly to the amygdala. The thalamo-amygdala route has a less sophisticated processing capacity and would be capable of transmitting lower-level sensory features. Memories formed in these ways would not be open to deliberate recall, but could be accessed automatically by cues, particularly perceptual cues, similar to those recorded in the fear memory.
Recent research appears to indicate that stress has very different effects on the hippocampus and the amygdala (Metcalfe & Jacobs, 1998). The physiology of the hippocampus under acute stress mirrors the Yerkes–Dodson inverted-U shaped function for cognitive performance. The effect of exposure to glucocorticoids is that activation of hippocampal neurones first increases but then declines, with the result that the continuity of hippocampal function is impaired under very high levels of stress. As a result, there will be adverse effects on declarative memory (Bremner et al., 1995; Metcalfe & Jacobs, 1998) i.e. less evidence of binding of individual features into a coherent whole or of location in a temporal and spatial context. There will also be adverse effects on habituation and extinction (Pitman et al., 2000). In contrast, the functioning of the amygdala appears generally to be enhanced as stress increases, consistent with the formation of overly strong conditioned responses (Pitman et al., 2000).

These memory systems, and the effects of stress upon them, provide a plausible neural substrate for the verbally accessible and situationally accessible memories proposed by Brewin et al. (1996) and for the symptoms of PTSD. In particular, they can account for the special qualities of flash-back memories. As previously noted, flashbacks are a highly perceptual form of memory that are elicited automatically and are only under limited conscious control. They have been claimed to be relatively stereotyped and unchanging even after multiple recall episodes (van der Kolk, 1996), whereas ordinary memories are altered by repeated recall (Estes, 1997). They are also reexperienced in the present, i.e. they do not possess an associated temporal context. All these features are suggestive of an image-based, non-hippocampally dependent form of memory (but note that the terms “nondeclarative” or “implicit” memory would not be appropriate as there is some conscious recall of the learning episode). From a neuroanatomical perspective it is interesting that the amygdala projects strongly to almost all regions of the brain involved in visual processing, including occipital cortex. The function of these projections is poorly understood, but one possibility is that they could support the experience of flashbacks. Given the highly visual nature of most reexperiencing in PTSD, it is also interesting that the amygdala has many more anatomical connections with visual than with auditory areas of the brain (Amaral, Price, Pitkänen & Carmichael, 1992).

6. The normal response to trauma

Having reviewed the relevant cognitive science findings, we are now in a position to amplify dual representation theory and put forward a more detailed model of the response to trauma. Consistent with proposals by several authors including Metcalfe and Jacobs (1998), Pitman et al. (2000) and van der Kolk (1996), a key component is the relative functioning of the amygdala and hippocampus. Owing to the stress-induced release of glucocorticoids and their effects on the hippocampus, verbally accessible memories of the traumatic event are likely to show some degree of disorganization, degradation, and incompleteness. However, in most cases the hippocampus will be able to support some continuing narrative of events. Memory deficits are likely to centre around transient periods of intense emotion associated with impaired hippocampal processing (‘hot spots’). Depending on the length and intensity of the trauma, these periods may range from a matter of seconds to minutes or occasionally hours.

Individuals asked to deliberately retrieve such memories do indeed report that their recollections
are relatively unclear and lacking in detail, poorly ordered, and poorly remembered (Tromp et al., 1995). In contrast, spontaneously accessed situationally accessible memories will contain a higher level of perceptual detail and are more likely to involve interconnected scenes (Hellawell & Brewin, 2000b). Any relative omission of hippocampally-processed information in VAM during these periods of intense emotion will also result in a greater probability of the amygdala being activated by trauma reminders and the person experiencing a sense of current threat (see Ehlers & Clark, 2000).

This leads to the interesting possibility that the reexperiencing of trauma in the form of flashbacks, which is common directly after a traumatic event, plays a critical role in transferring information from the non-hippocampally dependent SAM memory store to the hippocampally-based VAM system. By deliberately focusing attention on the content of the flashbacks, individuals can effectively recode the additional sensory information associated with periods of intense emotion into verbally accessible memory. In so doing, providing the danger has ceased, the information will acquire a context which includes temporal location in the past, cessation of immediate threat, and restoration of safety (see also Foa & Rothbaum, 1998). This in turn will assist the process whereby reminders of the trauma are inhibited by cortical influences from activating the person’s panoply of fear responses. Instead of reminders being processed by a memory system that does not discriminate between present and past time, the more sophisticated processing afforded by the hippocampus, with its access to the whole of autobiographical memory, will enable the event to be located in its appropriate context.

However, because information is being transferred utilising working memory, a limited-capacity system, it is likely that repeated flashbacks will be needed before the cortex is able to construct representations of the event that are detailed enough to inhibit amygdala activation. The number of flashbacks is likely to depend on two main factors. The first is the extent of the discrepancy between the amount of information coded into verbally and situationally accessible forms of memory. This in turn will depend on the efficiency of verbally accessible memory during critical periods of the trauma, and the extent to which attention was restricted. The more the person was able to pay close attention to the unfolding events, the more complete their VAM representations are likely to be. The second factor is the person’s willingness to attend to and process flashback content rather than distract themselves from these often unwelcome experiences. Sustained attention to flashbacks should theoretically promote information transfer and lead more rapidly to amygdala inhibition.

Let us follow other theorists in assuming that memories can be conceptualised as consisting of sets of features or attributes (e.g. Estes, 1997) so that, for instance, a particular scene in memory could be described as possessing 20 features (F1–F20). The suggestion is that the more features of the situationally accessible memory are represented in verbally accessible memory, the more efficient the VAM memory will be at inhibiting amygdala activation (see Fig. 1). To begin with, the VAM memory is likely to contain few features (say, F1–F7). Exposure to trauma reminders containing only this limited set of features will result in cortical inhibition of the amygdala. However, exposure to any trauma reminders containing features F8–F20 will be likely to activate the amygdala and lead to a flashback. The reexperiencing of the event in the flashback leads the body to respond as though to a current source of danger. Thus, for example, the reexperiencing of an object moving rapidly towards the person may cause the body to respond as if to a currently moving threat with a startle response (Hellawell & Brewin, 2000b). As the number of features...
in the VAM representation grows, fewer trauma reminders are able to activate the body’s defensive reactions.

With repeated hippocampal reinstatement of the trauma memory, a corresponding representation will be consolidated in the cortex. This means that the VAM memory will not have to be reconstructed each time the person encounters a trauma reminder—rather, there will be a stable, perma-

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**Fig. 1.** Completeness of verbally accessible memories and activation of the fear system.
nent representation that can exert the appropriate inhibitory influence on the amygdala quickly and efficiently. Theoretically, if all the relevant features of the SAM memory for critical scenes were represented in the VAM memory, the amygdala should remain permanently inhibited. In practice, though, SAM representations are likely to remain more detailed and thus the return of fear will always be a possibility given the right combination of sufficiently detailed trauma reminders.

Another aspect of the normal response to trauma is also likely to follow from repeated episodes of processing of trauma information within the ordinary autobiographical memory (VAM) system. Presentation of neocortical networks with this information, interspersed with recall of pre-trauma data, will promote the interleaved learning necessary for the integration of discrepant information into pre-existing knowledge structures. These structures will then gradually elaborate and reorganise themselves to accommodate the knowledge of events that may have severely challenged prior beliefs and expectations and led to unpleasant emotions such as guilt and anger. We may speculate that this form of slow learning may be one of the processes underlying the “emotional processing” (Rachman, 1980) or “assimilation” (Stiles, Elliott, Llewelyn, Firth-Cozens, Margison, Shapiro et al., 1990) of events. When successfully accomplished individuals will no longer feel as though the traumatic event is “unreal” or continue to inhabit an internal world in which the event never happened. In order to overcome secondary emotions deriving from the loss of cherished ideas or goals, individuals may in some instances be forced to make profound changes to their view of themselves and the world. This reorganization may even lead to the subjective conclusion that the person has benefited in some way or has become “a better person” as a result of an objectively most unwelcome trauma (Janoff-Bulman, 1992).

Finally, it is necessary to consider how, having overcome their flashbacks by constructing corresponding VAMs, the person prevents the intrusion of verbally accessible memories and thoughts about their trauma. While those memories still elicit a high level of secondary emotions there will be a diminution in the resources available to intentionally inhibit them from entering consciousness. However, as those emotions fade there is a corresponding increase in the effectiveness of ordinary inhibitory mechanisms that are designed to block the retrieval of unwanted material from memory. Recovery from trauma is therefore likely to involve the reinstatement of inhibitory capacities that have been temporarily suppressed by the intensity of the emotional response.

7. What goes wrong in PTSD?

In the foregoing account a successful trauma response was related to the creation of detailed VAM representations that were fully integrated with pre-existing knowledge structures. Creating detailed VAMs can occur either during the trauma or afterwards, through deliberate focusing on flashback content and repeated conscious processing of detailed information about the trauma. The corollary is that failure to create these representations will result in a considerable amount of trauma information residing solely in the SAM system, with SAM memories being vulnerable to reactivation by trauma cues and failing to be inhibited by higher-level cortical representations. Similarly, failure to repeatedly process and compare pre-trauma and post-trauma information within the VAM system leaves the individual vulnerable to catastrophic interference with previous beliefs and assumptions, resulting in overaccommodation or its counterpart, overassimilation.
The greater the interference with the continuity of hippocampal processing during the trauma, the more likely VAM representations are to be impoverished. Additionally, high levels of stress may reduce the effective operation of parts of prefrontal cortex, reducing the efficiency of memory encoding and of supervisory control. An example of such impairment is provided by peritraumatic dissociation, which involves alteration in mental state and a detachment from ongoing experience during the trauma. For example, events may be subjectively slowed down or viewed from an alternative (“out of body”) perspective. Peritraumatic dissociation is also associated with an increase in spontaneous memory intrusions (Holmes & Brewin, 2000) and with disorganization in deliberate trauma recall (Murray et al., 2000). This type of dissociative response may be related to the surrender of supervisory control that is subjectively experienced as helplessness (Reynolds & Brewin, 1999), and both peritraumatic dissociation and helplessness or mental defeat are related to the development of PTSD (Brewin, Andrews & Rose, 2000; Ehlers, Maercker & Boos, 2000; Koopman, Classen & Spiegel, 1994; Murray et al., 2000; Shalev, Peri, Canetti & Schreiber, 1996). During reliving there is likely to be a reinstatement of any dissociation, helplessness or defeat states, making it more difficult to carry out strategic activities such as deliberate focusing on the content of flashbacks. Under these circumstances there may be little if any spontaneous transfer of information from the SAM to the VAM system, and consequently no therapeutic benefit.

In addition to the initial impairment in declarative memory resulting from the effects of stress on the prefrontal cortex and hippocampus, VAM representations should remain impoverished when there is marked avoidance of trauma reminders and flashbacks. Avoidance stems in many cases from a desire to not reexperience the distress and horror caused by trauma. Unwanted emotions like anger, shame, and guilt, arising from negative cognitive appraisals carried out during or after the trauma, may also add considerably to the aversiveness of memories. Consistent with this prediction, avoidance and numbing symptoms are particularly important in determining who develops PTSD (Brewin, Andrews, Rose & Kirk, 1999; North, Nixon, Shariat, Mallonee, McMillen, Spitznagel et al., 1999). Many of the most consistent predictors of PTSD following trauma, such as previous traumatic stress and psychiatric disorder (Brewin, Andrews & Valentine, 2000), may have their effects through this mechanism. More generally, any factor that interferes with the construction of a detailed, consciously accessible memory for intense moments of the trauma would be predicted to lead to a worse outcome.

Brewin et al. (1996) proposed that unsuccessful adaptation to trauma can result in two different kinds of outcome, chronic processing of trauma memories and prematurely inhibited processing. Chronic processing involves a failure to prevent trauma reminders from constantly activating memory representations and bringing them into consciousness. This outcome can be linked to overaccommodation, in which the person reacts to the trauma by labelling a wide variety of innocuous situations as potentially threatening, unpredictable, or unfair. Alternatively, the person may label themselves as weak, bad, or inadequate. This form of catastrophic interference can have a number of adverse effects. One is to vastly increase the number of cues that will potentially elicit cognitions related to the trauma, thereby inducing a constant sense of current threat (see also Ehlers & Clark, 2000).

Another adverse effect may be to generate secondary emotions such as anger and guilt, which in turn increase the aversiveness of flashbacks and prompt ruminative responses. Ruminations include evaluative thoughts that assign blame and elaborative thoughts involving feared or worst
outcome scenarios (Merckelbach, Muris, Horselenberg & Rassin, 1998; Reynolds & Brewin, 1998). These responses are associated with a poor outcome (Ehlers, Mayou & Bryant, 1998) although we do not yet know why. One possibility is that flashbacks, ordinary memories, and ruminations provide mutual cues that trigger each other. The high degree of accessibility of thoughts and vivid memories is in turn likely to increase the estimated probability of such traumatic events occurring again (MacLeod & Campbell, 1992), thus maintaining the sense of threat. Alternatively, the emotions generated by these appraisals may use up resources shared with inhibitory mechanisms and interfere with their effectiveness. Another possibility is that ruminations have the function of avoiding unwanted memories and therefore prevent the individual from creating detailed VAMs (cf. Borkovec & Lyonfields, 1993).

Prematurely inhibited processing may be linked to the counterpart of catastrophic interference, overassimilation. Overassimilation involves the preservation of pre-existing knowledge structures by the conscious construction and rehearsal of a restricted, minimized, and likely distorted version of the traumatic event. In memory terms, this may be seen as involving the consolidation of a partial trauma memory containing a limited number of selected features. Consolidation in the neocortex will produce a representation that is readily activated as a whole by corresponding trauma cues, removing the need for the elaborate reconstruction of events when confronted by each reminder. The partial memory can to some extent be integrated with existing knowledge providing the person does not search for and attend to the more detailed representations that are available to them, for example in flashback form, and that contain additional or contradictory information.

One effect of selectively rehearsing a partial and distorted version of events may be to limit the number of weak trauma cues that are likely to accidentally activate trauma memories. Also, through the process of retrieval-induced forgetting (Anderson & Spellman, 1995), the original VAM representations are likely to become increasingly difficult to recall. If combined with other strategies, for example avoidance of the trauma scene and related situations, it may be possible to indefinitely postpone further processing of memories so long as only weak trauma reminders are encountered. However, SAM representations remain available to be activated in the future by strong or unexpected trauma reminders, and there will be no corresponding VAM representations to inhibit amygdala activation. Individuals thus remain vulnerable to delayed onset PTSD, which in some cases may not happen for many years.

8. Psychological treatment of PTSD

Standard treatment directed at PTSD symptoms generally involves two elements, which may be used separately or together: The detailed and repeated exposure to traumatic information, and the modification of maladaptive beliefs about events, behaviours or symptoms. Both exposure and cognitive methods have been demonstrated to be effective (Foa & Meadows, 1997). In accounting for the success of prolonged exposure, Foa and Rothbaum (1998) proposed that erroneous information in the trauma memory is corrected by the incorporation of new and incompatible information. They further proposed that this process is rendered more difficult when trauma memories are disorganized and fragmented, whereas integration with existing memory structures is facilitated by the organization and streamlining of these memories. Similarly, Conway and Pleydell-
Pearce (2000) argued that traumatic memories are problematic because they are poorly elaborated and poorly integrated into the general autobiographical knowledge base. As well as making intentional recall difficult, they argued that poor elaboration also facilitates spontaneous cue-driven recall in the form of flashbacks.

In contrast to theories proposing the correction, reorganization, and streamlining of a single level of trauma representation, dual representation theory holds that therapy involves acting on both SAM and VAM systems. The human and animal data on the durability of fear conditioning, and the ease with which fear responses can be reinstated following extinction, provide a strong hint that fear memories encoded in the SAM system remain intact and are not directly modified by psychological therapy. Therapy assists in the construction over time of detailed, consciously accessible memories in the VAM system which are then able to exert inhibitory control over amygdala activation. According to this view, what suppresses flashbacks is the representation of critical retrieval cues in the VAM system that were previously only represented in the SAM system. These cues must be represented in a form that enables them to be deliberately recalled, and they must be associated with a past temporal context and a sense of current safety. That is, the cues must be identified as belonging to a specific past event which does not now constitute an ongoing threat. Thus, an increase in global memory elaboration or organization should not predict recovery if such cues could not be intentionally recalled, or were exclusively reexperienced in the present, or if the individual felt currently threatened.

If the global organization of the entire trauma memory is not critical, then it may not be necessary to have patients recall the entire event during a series of sessions and then repeatedly review the material during homework practice, which is a standard element of many types of reliving or exposure therapy. Rather, it may be possible to terminate flashbacks prior to patients achieving a coherent, streamlined narrative. Like Ehlers and Clark’s (2000) cognitive model of PTSD, dual representation theory suggests a modification to standard methods involving a more specific focus on critical retrieval cues associated with very high levels of distress in the narrative. Having identified these hot spots during the initial account of the trauma, therapists can assist patients to focus and maintain their attentional resources on these specific moments and recode the events and images into verbally accessible memory such that they can later be intentionally retrieved. The attentional focus should include both the external events represented in the traumatic images and internal events such as fleeting thoughts and bodily changes.

Consistent with therapists who emphasize a graduated approach to trauma recall, particularly when it has occurred early in life (e.g. Herman, 1992) dual representation theory suggests that arousal levels must be carefully managed during this process. If arousal becomes too high, frontal and hippocampal activity will again become impaired and the person will reexperience the trauma without transferring information from the SAM to the VAM system. With complex or long-lasting traumas it is likely that repeated episodes of recall will be necessary, with the process being terminated each time the person dissociates to the extent that he or she is no longer able to reflect consciously on the material coming to mind. In order to complete information transfer it may be necessary to divide the trauma episode or episodes into smaller units, and to construct a hierarchy from less distressing to more distressing moments. There is evidence that typing the trauma narrative on a typewriter or word processor reduces levels of arousal relative to writing longhand (Brewin & Lennard, 1999) and may be a useful intervening step. If information transfer is being implemented successfully, there should be a steady increase in the amount of the trauma narrative that the patient is able to retrieve and reflect upon before beginning to dissociate.
On exposure to trauma reminders these new representations in the VAM system will compete with the older SAM representations to determine which representation is retrieved. To begin with, the older representations may enjoy a retrieval advantage as they have already been spontaneously retrieved many times in the weeks and months following the trauma. Amygdala inhibition should be enhanced by incorporating into the new VAM representations features which confer a retrieval advantage over the old trauma memories in the SAM system. Theoretically, such an advantage might be gained from making the new representation highly distinctive. It has long been known that the encoding of unusual, distinctive attributes provides a unique specification of the target memory and facilitates retrieval if a component of the distinctive processing is available at test as a cue. In other words, the memory has become highly discriminable (Eysenck, 1979; Lockhart, Craik & Jacoby, 1976). More recent evidence goes further in demonstrating that the encoding of unique attributes with the target memory enhances retrieval even when these cues are not available at recall. Even general cues can access these distinctive encodings (Hunt & McDaniel, 1993; Hunt & Smith, 1996). Extrapolating to a trauma context, this would suggest that any trauma reminder would be likely to access the new VAM memory providing the representation was sufficiently distinctive.

Interestingly, there are a number of therapeutic procedures which may be effective in incorporating distinctive attributes into VAM representations of trauma. Eye movement desensitization and reprocessing (EMDR) is a treatment for PTSD that has been claimed in a meta-analytic review to yield similar benefits as behaviour therapy but in a significantly shorter time or with significantly less homework (Van Etten & Taylor, 1998). The core of the method involves visualising the worst moments of the trauma while simultaneously holding in mind a current negative cognition concerning the event, and attending to a concurrent stimulus such as the therapist’s finger movements in front of the face or taps on the hand (Shapiro, 1995). Patients attempt to distance themselves from the traumatic images, allow new thoughts, images, and associations to come to mind, and report on their mental contents at regular intervals. If the claims for EMDR are shown to be soundly based, dual representation theory suggests a possible mechanism that has so far not been considered. Theoretically, the real-time stimulus provided by the therapist’s actions, which impinge directly on the patient as they are attending to the traumatic image, could function to encode a very distinctive attribute with the new VAM representation. Trauma reminders would then tend to lead to the rapid reinstatement of this memory in preference to the older representations. This explanation would be consistent with the finding that the precise nature of the visual or tactile stimulation does not seem to be critical to the success of EMDR (Cahill, Carrigan & Frueh, 1999).

Other forms of therapy involving distinctive attributes in the form of imaginal reconstruction of traumatic events have also obtained encouraging results (Hackmann, 1998). For example, sexual abuse survivors may replay traumatic moments and imagine their adult self intervening to prevent the occurrence of harmful and frightening acts. Once again, these techniques are claimed to bring about a relatively rapid reduction in anxiety, without requiring a repetitive and lengthy reworking of the trauma narrative. However, in encoding distinctive attributes paired with the original trauma images, imaginal reconstruction is consistent with the principle of trying to confer a retrieval advantage onto consciously accessible memories in the VAM system.

As far as more cognitive approaches to the treatment of PTSD are concerned, our review suggests that the establishment of new and stable cognitive structures in VAM depends at least
in part on interleaved learning. This process of repeated information review and comparison between pre- and post-trauma states may be severely impeded by negative emotions or ‘stuck points’, resulting in avoidance or in the rehearsal of partial and/or distorted versions of the trauma. These over-assimilated trauma representations require identification, challenge, and modification (e.g. Resick & Schnicke, 1993). One outcome of this premature inhibition of processing may be that the person has alternative, competing representations in the VAM system, some containing and some omitting important information about the event. As noted by McClelland et al. (1995), such knowledge systems are inherently unstable. Inputs such as unexpected trauma reminders may cause a switch in the representations that are currently active in working memory, accompanied by strong emotional reactions. We may also speculate that alternative, competing knowledge representations, about which patients have differing degrees of simultaneous awareness, contribute to a sense of unreality about the trauma.

As noted above, cognitive appraisals may at times lead to a variety of emotions occurring peri-traumatically and therefore being represented in the SAM system as well as the VAM system. It is worth asking whether cognitive restructuring of the VAM system undertaken during therapy will generalise to the SAM system, or whether patients may be left agreeing with the logic of the therapist’s argument but being unable to prevent the unwanted cognitions and emotions being reinstated during reliving episodes. The informational isolation of the SAM system suggests that the latter may sometimes be the case. Dual representation theory therefore suggests that, in those cases where negative appraisals have occurred during the trauma rather than exclusively post-trauma, cognitive interventions may have to be additionally implemented in such a way that they make contact with the SAM representations. For example, having first rehearsed challenges to negative beliefs during a non-reliving session, patients may benefit from repeating and rehearsing these while partially reliving the trauma in the present (see Ehlers & Clark, 2000; Grey, Young & Holmes, 2000).

9. Conclusion

The study of trauma reveals many complex processes that are poorly understood. One of the most fascinating concerns the paradoxical nature of trauma memories, which may be vague or vivid, intrusive or quiescent, under or out of control, and experienced in the present or the past. There is now a large amount of converging evidence from clinical observation, neuroanatomy, and cognitive science to suggest that the many facets of trauma recall reflect the operation of two independent types of memory that are differentially affected by extreme levels of stress. Many of the puzzling features of PTSD can be understood in terms of the relative efficiency of these two systems and of the interaction between them, drawing on some basic principles of memory functioning derived from laboratory research.

Relating this cognitive science perspective to the treatment of PTSD implies that the detailed reconstruction of a trauma narrative during therapy is indeed important, but not for the reasons that are usually put forward. Instead, I suggest that the purpose is to consolidate a verbally accessible representation of the trauma in long-term memory, so that it can exert a rapid and effective inhibitory influence over the amygdala. In order to achieve this it may not be necessary for the entire trauma representation to be particularly well elaborated or coherently organised. What is
important is that it contains the most critical retrieval cues, for example the colours, shapes, or types of movement associated with sharp increases in threat. It may also be helpful if the new representation is encoded with very distinctive attributes. A quite separate function of therapy is to resolve discrepancies with preexisting hopes, beliefs, or assumptions that reflect the impact of the trauma on cognitive appraisal of the self, other people, and the future. Negative emotions generated by these appraisals are likely to interfere with the interleaved learning that is necessary for new stable knowledge structures to develop. Cognitive interventions will be required to modify these appraisals. Negative post-trauma appraisals may be modified by standard methods, but peri-traumatic appraisals may have to be challenged while patients are partially reexperiencing their trauma.

The next few years promise to yield important new insights into PTSD and its treatment. Cognitive science provides a wealth of data and theoretical concepts that can inform the development of testable models concerning trauma, memory, and emotional dysfunction. This process can best be hastened by articulating as clearly as possible alternative models and devising empirical tests to distinguish between them. Undoubtedly neuroimaging will contribute to this process and tell us more about the structure and functioning of the traumatised brain. Equally important will be the collection of focussed phenomenological and experimental data that shed light on the cognitive processes typical of PTSD, particularly those involving different kinds of intrusive thoughts and memories. Our understanding of current therapeutic procedures is remarkably rudimentary given their effectiveness, and further advances in treatment are likely to depend on the development of convincing theoretical models.

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References


