Integration of Traumatic Memories

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ABSTRACT

In this paper, I will discuss a short review of traumatic memories based on neuroscience and information theory. Based on neuroscience and information theory, I will present a new technique that may integrate fragmented traumatic memories. The presented technique is based on slowing down the process of recall of the traumatic memory as well as adding new information at the time of recall, which may result in re-encoding these memories during the reconsolidation phase. The resulting rewritten memories seem to last for a very long time.

Keywords: neuroscience, trauma, memory, information theory, re-encoding, reconsolidation

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In a previous paper (Shahri, 2018), I briefly discussed traumatic memories from the perspective of neuroscience and information theory. Based on neuroscience and information theory, I presented a new technique that may rewrite traumatic memories during reconsolidation. The technique presented in this paper is based on slowing down the process of recall and adding new information based on elaborative repression. This adds new information at the time of recall of the traumatic memories that may result in re-encoding these memories during reconsolidation. The resulting rewritten memories seem to last a very long time.

Memory, in its most general sense, is defined as what we consciously recall from past events. But memory is more than what we consciously recall from the past (Siegel, 1999). In particular, if a certain neural pattern has been activated in the past (in response to external or internal stimuli), then the probability of activating a similar pattern in the future is enhanced. This is how we remember and learn from the past. "The increased probability of firing a similar pattern is how the [neural] network remembers" (Siegel, 1999, p. 24). Siegel further writes, "Memory storage is the change in probability of activating a particular neural network pattern in the future" (Siegel, 1999, p. 25).

Our brain generally does not encode and save every experience as explicit memory, or else we would be inundated with so much information so that we would not be able to function. It seems that the more emotionally intense our experience is, the higher the probability of its encoding and recall. The event is labeled as important by the amygdalae, which are parts of the limbic brain involved in experiencing emotions. Likewise, less emotionally intense events have a lower probability of being encoded and saved (Siegel, 1999). It is important to note that events that are filled with fear or terror, or are overwhelming, may not be encoded by the hippocampus, another part of the limbic brain involved in memory and emotions. Several factors such as amygdalae discharge, or the release of various neuroendocrine hormones, including noradrenaline and corticosteroids, may inhibit the functioning of the hippocampus, thus blocking the encoding of the event and later recall. However, although explicit memory is impaired, these events may be stored as fragments in implicit memory (Siegel, 1999). Implicit memory stores the emotional dynamics of events, not their contents. Therefore, when implicit memory is reactivated, it is not associated with a sense of time, place, and sense of self in time, nor is there a sense that something is being recalled. Although implicit memory can be online from early infancy and even prenatally (mainly stored in the limbic system), it is only after roughly the second year of life that the hippocampus is developed enough to encode explicit memory.

It is important to mention that the recall of (degraded) past memories recovers some parts of these memories, and may further augment these memories for meaning (elaborative repression), in an effort to reduce the uncertainty and increase predictability to reduce arousal (Erdelyi, 2006).

A Neuroscience Perspective

Human memory formation is associative, which means that new information is better remembered if it is associated with previously encoded events or memories. The more emotionally meaningful the association, the more effective the encoding of new information will be. Because of the associative nature of memory, encoding can be improved when new information is associated with other information already encoded in long-term memory. This results in the formation of a coherent narrative that is already familiar (Mastin, 2010).

LeDoux (1996, 2002) argues that the only memories that are unchanged are memories that have never been recalled. When a memory is recalled, it goes through changes. This is due to the associativity of memory. Thus, when a memory is recalled, it is associated with stimuli in the environment and then reconsolidated. LeDoux (1996, 2002) further argues that this gives us the opportunity to modify memories during the recall and reconsolidation.

In a separate study from LeDoux's laboratory, Diaz-Mataix, et al (2013), write: "Traumatic fear memories are strong and persistent and form the basis of several pathological disorders, including post-traumatic stress disorder (PTSD) and anxiety disorders. The search for procedures that may render these memories sensitive to pharmacological or behavioral treatments is thus critical. It is known that after memories have been consolidated into a long-term state they can enter a new labile state when reactivated prior to being reconsolidated. During this lability window, it is believed that memories are updated and new elements are incorporated." In this study, the authors indicate that while in the labile state, memories can be modified by the introduction of new information during reconsolidation. This modification takes place due to the associativity of memory, which essentially indicates that recalled memory will be associated with the additional information during reconsolidation, and may thus modify the original fear-based and aversive memories.

An Information-Theoretic Perspective

Neural connections, via their axons and dendrites, can be viewed and considered as communication channels with limited capacity. This indicates that the firing of neurons and the production of action potentials or spikes (Shahri, 2017) are governed by fundamental limits that can be quantified. Figure 1-A below shows a discrete grid (marked by dots in the picture) laid over a picture of salamanderfish, which is used to measure the response of one ganglion cell (responding to darkness) of the salamanderfish when moved on the discrete points of the grid. In this experiment, a ganglion cell that responds to darkness (a cell in the retina) of a salamanderfish is placed over the location of the dots in the picture, and then the response is measured. Figure 1-B shows the firing of the ganglion cell when moved across a column (over the location of the dots) marked by arrows. Figure 1-C shows the reconstruction of the captured image of the salamander based on the latency of the spikes (action potentials); that is, the earlier the firing, the darker the actual scene is. Figure 1-D depicts the reconstruction of the captured image of the salamander based on the spike counts. One can appreciate that sensory processing is limited by the firing of spikes. That is, if the firing of ganglion cells cannot keep up with the stimulus, the sensory information will not be encoded in its entirety, and information will be lost. This argument is essential to the understanding of the nature of traumatic memories. Specifically, when sensory information is massive and beyond the capacity of neural firing (action potentials or spikes) to fully capture it, information is lost, and the narrative related to the sensory stimuli can at best be preserved in fragmented and dissociated forms. Traumatic memories, in essence, can perhaps be memories that correspond to events that could not be fully captured and coded in their entirety, due to fundamental limits on the rate of firing of spikes and action potentials. Furthermore, since a coherent narrative is not constructed that integrates the fragmented traumatic memories, these memories will contain a high amount of information (unpredictability).

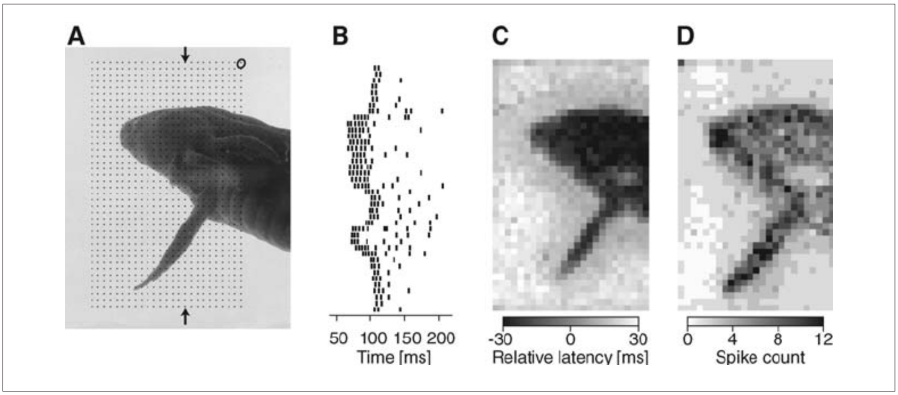

Figure 1. *Response (Spikes) of Ganglion cell of a Salamander (Gollisch & Meister, 2008)*

The encoding of sensory information in the brain must be efficient, and neurons must express their full output capacity in order to encode sensory information (with little loss of information), subject to fundamental limits. In the field of neuroscience, this is known as the *efficient-coding hypothesis*. Loh and Bartulovic (2014) write: "The Efficient Coding Hypothesis, suggests that sensory relays recode sensory messages, so that their redundancy is reduced, but little information is lost. Coding to reduce redundancy eliminates wasteful neural activity, and also organizes sensory information such that an internal model of the environment causing the past sensory inputs to build up, while the current sensory situation is represented in a way that simplified the task of the part of the nervous system which is responsible for learning and conditioning." The efficient-coding hypothesis, also known as the redundancy-reducing hypothesis, was introduced by Barlow (1961).

Barlow's Redundancy-Reducing Hypothesis (1961)

Horace Barlow (1961) argued that laws of nature are such that they bring order and simplicity to our complex sensory experiences. He further argued that the communication and coding of information in the brain should be fast, precise, and minimally redundant (efficient), and should work regardless of interference in the communication channel. The associativity of memories can be considered as a direct corollary of Barlow's hypothesis, in that by encoding associative information (memory) together, redundancy is reduced, as memories are not encoded in separate and redundant parts. Another corollary of Barlow's hypothesis, which I will emphasize, is that when a memory is recalled, then all associated previously encoded memories are also primed for recall, and thus have a higher probability of being recalled. Due to the associativity of memory, correlated sensory information and events are encoded together. It is also important to note that the brain does not simply compute the correlation between sensory inputs corresponding to event X and all events Y that occurred in the past. It starts the computation with events that have higher information (emotional) content, and are thus more significant. Not only does neuroscience prove this assertion, but it is also important to note that this would have had significant evolutionary advantages, in that previously encoded events with high information content was generally more important and more relevant to the survival of our species.

A corollary of Barlow's hypothesis is that our nervous system moves toward predictability and avoids "high information" and unpredictability. Viewed somewhat simplistically, our brain can be thought of an information-processing machine constantly trying to reduce the unpredictability of sensory input by correlating and comparing sensory input to encoded events with high information content that occurred in the past, and finding the closest match, thus reducing redundancy in the encoding of the sensory input. Pfaff (2006) relates brain arousal and emotion to information. Events that contain more information are less likely to occur, and can result in emotional arousal. The converse is also true in that emotionally significant events contain more information, and are more unpredictable. To illustrate this point, the interested reader could look at the checkered figures depicted on the right side of

Figure 2, and notice which figure results in more arousal (attracts attention). As our vision is peripheral, figures that are more horizontal carry less information, have higher probabilities of occurrence, and thus contain less information, while figures that are more vertical carry more information and have lower probabilities of occurrence, and thus result in higher levels of arousal and emotional response (the probability of occurrence of an event is inversely proportional to its information content). The figures on the left of figure 2 depict the firing of action potentials of ganglion cell of a Rhesus monkey. The interested reader should observe that the ganglion cell responds with more spikes and action potentials to the vertical figure, and not as strongly to the horizontal figure, as the Rhesus monkey's vision is also more peripheral.

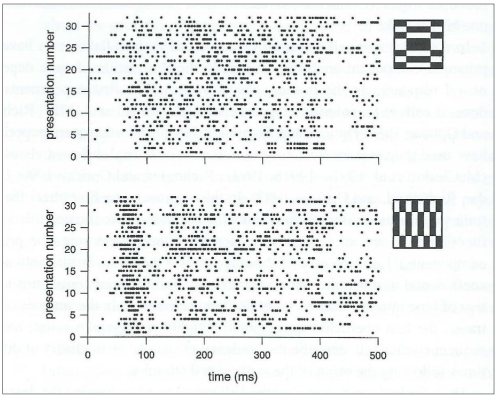

Figure 2. *Rhesus Monkey's Ganglion Cell response to different patterns (Rieke, Warland, van Steveninck, & Bialek, 1999)*

In this section, I discussed and showed that traumatic memories correspond to events with high information beyond the capacity of the firing rate of neurons to be represented and associated with previously encoded memory. Traumatic memories may thus be encoded as dissociated and fragmented part-memories that contain high amounts of information (unpredictability - less likely to occur), and are more emotionally significant. This explains why traumatic memories are state-dependent, and can be easily triggered and result in emotional dysregulation. The treatment of trauma then requires the integration of highly emotional (high information content) fragmented memories and reduction of their information content (unpredictability - less likely to occur).

In the next section, I introduce a technique that seems to be highly effective in the integration of fragmented traumatic memories. This technique reduces the unpredictability of traumatic memories, possibly resulting in the integration of these memories.

Reprocessing of Traumatic Memories Before Reconsolidation

In the previous section, I discussed a neuroscientific as well as an information-theoretical perspective regarding the formation of traumatic memories. I also laid the theoretical foundation and groundwork for the technique that I present in this section that may integrate fragmented traumatic memories during the reconstruction phase.

My approach to the potential integration of traumatic memories is based on slowing down the reprocessing of traumatic memories so they can be re-encoded, but this time with less unpredictability. This re-encoding of high arousal and emotionally charged memories results in the conversion of these aversive memories, through elaborative repression (Erdelyi, 2006), to more predictable and less emotionally charged and benign memories. The efficacy of this proposed technique is predicated on a strong therapeutic relationship, which functions as a predictable holding environment and safe container.

The Technique and its Application

I indicated above that our nervous system tends to move toward predictability and reduction of entropy (uncertainty). The technique that I present in this section precisely aims at the reduction of uncertainty.

In working with clients' traumatic memories, I sit across from them (Figure 3). I then ask the clients to recall the traumatic memory, but I ask them to recall it very slowly - one frame at a time (slow motion), and I further ask them to connect with me when they need to, that is, if the recalled material is overwhelming, and they need to feel my presence and support. Prior to the using this technique, I introduce the clients to what I mean by "connecting with me." I do this by asking them to be aware and feel the space between them and me. Awareness of this space is the somatic correlate of the connection between us. When they recall of traumatic memories in this way, they are less overwhelming, as the brain can process the high information (emotion) content of these memories, and possibly add extra information (elaborative repression), if need be, to make sense of the traumatic memory and integrate it. My presence with them and their connection with me serve to reduce arousal so that the brain can process the recalled memory, and the possible elaborative repression can fill in the gaps in the recalled memory.

I introduce the clients to what I mean by "connecting with me." I do this by asking them to be aware and feel the space between them and me. Awareness of this space is the somatic correlate of the connection between us.

When the change has occurred, I can usually observe it in the clients' faces. When these early memories, which are the blueprint for many future behaviors, are re-encoded and rewritten, clients generally feel freer, and do not function from their early traumas as often and as intensely. Please note that Barlow's redundancy-reducing hypothesis (Barlow, 1961) suggests that behavior, to a great extent, is based on earlier experiences; thus, when the adverse early memories are re-encoded, so are the future behaviors that are based on them.

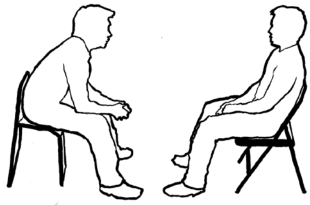

Figure 3. *Staying and connecting with the therapist*

In the following two case studies, I illustrate how I worked with two clients who suffered from traumatic experiences. In both cases, the intrusive memories have not returned (as reported by clients). I worked with these two clients more than twelve months prior to this writing, and there are no signs that these two clients are troubled by their traumatic memories of the past.

The Case of Kate

Kate was a woman in her late forties. She initially came to see me because of issues with her teenage daughter. Later in her work with me, she indicated that she would get very anxious and almost panic-ridden when she showered, and that she also could not go into a swimming pool or the ocean, and that even the thought of being in a swimming pool or the ocean would give her severe anxiety. In working with Kate on this issue, I asked if she remembered anything from her distant past that might have had some similarity to what she was feeling, such as being submerged in water, etc. Due to the associative nature of memory, I have realized that distant traumatic events responsible for the present-day behavior are frequently primed for recall when this question is asked. Kate mentioned that when she was about eight years old, she and her family, including her younger cousin, had gone to the beach. Her younger cousin went in the ocean without an adult watching her, and Kate felt that she might have been drowning. Kate went into the ocean to reach her cousin and save her, and in the process, she went underwater, as the water was deeper than her height. She indicated that she felt that she was going to die and was very scared. They were, of course, both rescued by a bystander, but the effects remained with Kate! In working with Kate, I asked her to recall what had happened, but slow it down to "one frame per second" so the events were happening very slowly. She did not need to talk about the recalled memory. I also asked her to stay in contact with me, and make connection with me when she needed it. During the course of the work, she connected with me several times (looked into my eyes and felt the space between us). After several minutes, the expression on her face changed, and she smiled. I asked her what had just happened. She replied that she saw herself going underwater, down to the bottom of the ocean, and imagined that I was watching her and that she was safe. She mentioned that when her feet touched the ocean floor, she gently pushed against the ocean floor and came up, and felt that it was like a game and somewhat enjoyable! She also indicated that she no longer felt anxiety when she thought of going into a pool or the ocean. During the next several sessions, I asked if she felt anxious when she took a shower or thought of going into the pool or the ocean. She responded that she did not feel anxiety related to water anymore. Many months have passed since our work, and she reports that she no longer feels anxious about being in a body of water nor about taking a shower.

The Case of Misty

Misty was a forty-year-old woman who came to see me because she was involved in a car accident, after which she was not able to drive and had a difficult time sitting in a car. She would get extremely anxious if she sat in a car, she reported. Misty mentioned that she was sitting in the back seat of their family van with her mother-in-law and her five-year-old son. Her husband was driving, and her father-in-law was sitting on the front passenger side. She indicated that they were driving on a freeway and were hit on the side by another car that had lost control. The van rolled over a few times and eventually came to a stop. When Misty came out of the initial shock she noticed that her son was not in the car, but found him outside of the car, standing in the freeway. Miraculously, no one in the car was badly injured, except for a few bruises. Misty was desperate and wanted to be able to drive again, and not feel so anxious when she sat in a car. The car accident that Misty was involved in had happened so quickly that her brain could not process what had happened, and the memory of the accident was very fragmented, causing arousal of her nervous system. My work with Misty involved the integration of the memory of the accident. I had to coach Misty on learning about connection and connecting with me. She learned fairly quickly, and was able to feel safe and connect with me. I then asked Misty to recall the memory of the accident, but one frame at a time. I also asked her to connect with me if she felt overwhelmed and scared, or if she just needed my support. She proceeded to recall her memory of the accident very slowly (one frame per second). During the course of her recall of the accident, she needed to make contact and connect with me, and she was able to fill the gaps in her memory that were left void due to the amount of information that needed to be processed by her brain, which was simply beyond its ability at the time of the accident; the neurons in her brain simply could not fire quickly enough to integrate all the sensory information. She was able to see her son being thrown out of the front window of the van, and then saw him landing on his feet safely on the side of the freeway. She was also able to see that everyone in the van was safe, and that no one was seriously injured. The gaps in her memory were filled by the addition of new information through elaborative repression. During the course of recalling this memory, another memory from her early childhood was recalled that we later processed using this same technique. Fourteen months have passed since she had this session with me, and since then she has been able to drive and otherwise function fairly normally. Although she first started sitting in the car, after a week or so she was able to drive in urban areas, and after a few weeks she was able to drive on freeways. To my knowledge, she has been functioning normally and her panic and anxiety are essentially gone.

Conclusion

In this paper, I briefly reviewed the formation of traumatic memories based on neuroscience and information theory, and presented a new technique that might integrate fragmented traumatic memories during the reconsolidation phase. This technique is based on slowing down the recall of traumatic memory, and adding new information through elaborative repression, which serves to fill the gaps in the traumatic memory. I discussed the theoretical validity of my approach using neuroscience as well as elementary information theory. I also presented two case vignettes to demonstrate how I apply this technique. Based on my clinical experience so far, it seems that the resultant rewritten memories may last for a very long time.

Implications for Practice

In this paper, based on neuroscience and information theory, I discussed how traumatic (and especially shock trauma) memories may be formed, and laid the groundwork for understanding the nature of traumatic memories: their fragmented and dissociated nature. I also discussed a technique that can be effective in the integration of traumatic memories. The technique slows down the recall of the traumatic memories within the safety of the therapeutic relationship. I would like to stress that this technique is by no means unique, and indeed any approach that can slow down the recall of traumatic memories in a safe therapeutic container may be effective. I discussed that based on Barlow's and the efficient coding hypotheses, the brain seeks predictability and reduction of entropy (uncertainty). The process of slowing down the recall of traumatic memories gives the brain the chance to possibly create a modified narrative (to fill in the gaps), a safe one this time, based on elaborative repression. The newly constructed narratives tend to persist, as they are more predictable and less arousing. I would also like to add that the presented analysis of traumatic memories may shed light on how various approaches to healing trauma work. My hope is that this analysis and theoretical discussion may pave the way for the development or refinement of current and future techniques that can be effective in the integration of traumatic memories.

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