

Studying to Fail: The Relationship Between Stress and Memory and the Implications for Students

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Abstract

This paper reviews current literature on the topics of stress and memory, and examines their relationship while emphasizing potential implications for students. The discussion begins with the underlying processes of the stress response and the impact that has on memory, with a focus on stress-induced retrieval impairment. Retrieval-induced forgetting is discussed with consideration of findings by Koessler et al. (2009) that stress has an inhibitory effect on the process. Variables that influence susceptibility to memory impairment, namely low extraversion (Law et al., 2012) and low arousal level of material (Buchanan et al., 2006; Goldfarb et al., 2019), are considered alongside suggestions for better study practices. Research is explored that demonstrates the effectiveness of retrieval practice as a defence against stress-induced retrieval impairment, and students are advised of the benefits that utilizing this practice may bring (Smith et al., 2018; Smith et al., 2016).

Keywords: acute stress, memory, retrieval-induced forgetting, retrieval practice, retrieval-impairment

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Imagine the following scenario: A student spends hours studying for an upcoming midterm, reading their notes to exhaustion. Once in the examination room, they find themselves unable to recall the information they so effortfully studied prior. This disappointing failure in retrieval, colloquially referred to as *blinking*, is all too common for students. How does a memory lapse like this occur? In this paper, a selection of current literature focusing on the interaction of acute stress and memory is reviewed, with the purpose of offering insights into the implications for students. Given the role of memory in education, dispersal of this knowledge could improve student study habits and help to explain poor performance under stressful conditions such as examinations. The paper will begin by outlining the underlying processes of the stress response and its relationship with memory, followed by an exploration of the concept of retrieval-induced forgetting, as well as factors that influence stress-induced retrieval impairment. Finally, the paper will conclude with a discussion of what the research suggests for student study practices. While stress is often an inescapable part of schooling, proper knowledge and tools may lessen or even eliminate the unfortunate effects it has on some students.

The Stress Response and Memory

Before examining the impact of the stress response on memory, one must first understand how memories are formed under normal conditions. The creation of a memory begins with encoding, in which perceived information is sent to the hippocampus to be transformed into a memory representation. Once transferred into long-term memory storage, that representation can be accessed and retrieved later on. Retrieval involves the recollection of contextual associations, accompanied by the reestablishment of cortical activity that occurred in the original experience (Gagnon et al., 2019). When a stressor is introduced, the processes of memory are altered in complex and varying ways.

Stress initiates the release of catecholamines (norepinephrine and epinephrine) and glucocorticoids (cortisol; Buchanan et al., 2006; Gagnon et al., 2019; Joëls et al., 2006; Koessler et al., 2009; Schwabe & Wolf, 2014; Smith et al., 2018). Schwabe and Wolf (2014) describe the stress response in three phases. The first phase is an immediate release of noradrenaline, followed several minutes later by the second phase involving a fast-acting cortisol release. The

third and final phase begins 1 to 7 hours after the initial stressor, with a slower-acting cortisol reaction. This has a direct impact on memory, owing to the vast number of glucocorticoid receptors in the hippocampus (Smith et al., 2018). Additionally, the highly stress-sensitive amygdala is known to alter the functioning of the hippocampus in the presence of a stressor (Goldfarb et al., 2019; Smith et al., 2018). The different actions of these neurochemicals lead to diverging effects on the encoding and retrieval processes of memory. Depending on the timing of the stressor, one may experience enhancement of encoding, while the process of retrieval may be impaired (Buchanan et al., 2006; Goldfarb et al., 2019; Smith et al., 2018).

It may seem counterintuitive that experiencing acute stress can both help and hinder memory, but with deeper analysis of the stages a logic emerges. Stress experienced at the encoding phase makes the context more salient, thereby inducing a more aware and focused state in which to create better associations (Gagnon et al., 2019; Goldfarb et al., 2019; Joëls et al., 2006; Schwabe & Wolf, 2014). This leads to improved retrieval in the absence of stress. If, instead, stress is experienced in the retrieval phase, actions such as recognition and recall are impaired (Buchanan et al., 2006; Schwabe & Wolf, 2014). Neurologically, this stress-induced retrieval impairment has been attributed to the third phase of the stress response outlined above by Schwabe and Wolfe (2014). The slower-acting cortisol release triggers a change from the normal hippocampus-led system of remembering to an instinctual fight-or-flight system that does not allow for details to be retrieved (Schwabe & Wolf, 2014).

Goldfarb and colleagues (2019) examined these time-dependent effects of stress on memory and uncovered differing results when stress was administered pre-encoding, post-encoding, or pre-retrieval. Stress presented prior to encoding enhanced memory for words that participants considered highly arousing, but only for associative memory. When stress was presented after encoding, researchers found that memory for highly arousing words was enhanced but the effect was limited to memory for parts of an event (item memory). These findings, while relevant to some, only apply to students who felt stress within the learning process. A more common setting for students to feel stress is an examination or test when retrieving previously learned knowledge. The final testing manipulation provides telling information for this setting, in that the presentation of stress before retrieval impaired all types of memory, regardless of the arousal rating of the words. These results show a clear negative effect of stress on retrieval of information.

Stress-induced retrieval impairment has indisputable implications for students as their performance is often quantified in terms of scores on examinations that are often, if not always, accompanied by some degree of stress (Gagnon et al., 2019; Joëls et al., 2006; Karpicke & Roediger, 2008; Koessler et al., 2009; Smith et al., 2018; Smith et al., 2016). It can be inferred that experiencing stress during an exam may lead to poorer performance in spite of efforts to prepare. Given that student academic performance is largely measured by successful retrieval and less on encoding processes, this will be the focus of the remaining sections.

Retrieval-Induced Forgetting

A phenomenon stemming from retrieval impairment with specific consequences for students is the concept of retrieval-induced forgetting (RIF). This occurs when retrieval of a memory is inhibited or suppressed by the previous retrieval of a similar memory (Koessler et al., 2009; Law et al., 2012). Given that academic tests are typically comprised of units within a common theme, this effect can be detrimental for students. Research by Law and colleagues (2012) as well as Koessler and colleagues (2009) demonstrates the procedure for studying RIF. Participants first learn item-pairs, such as “fruit-strawberry,” and are later tested by being given the first word of the pair and being asked to recall the second word. The learning phase is further manipulated to create two categories: Rp+ item-pairs, which are learned and later studied through retrieval practice (a technique that will be explained in a later section), and Rp- item-pairs, which are learned but not studied. During the recall phase that follows, a third control category (Npr item-pairs) is introduced as the participants are asked to recall words from pairs that they were never exposed to. The typical performance on this test is Rp+ items being readily recalled, while Npr and Rp- items are consequently inaccessible. RIF is shown in that the retrieval practice for Rp+ items inhibits the ability to recall Rp- items, with Rp- items often being recalled even worse than Npr items. In summary, word-pairs that are learned but not studied are recalled worse than word-pairs never learned at all; this points directly to the importance of studying material in order to have future access to the memory.

Results found by Koessler and colleagues (2009) in their exploration of RIF and stress have particular relevance to students. The authors found that RIF was diminished on free-recall tests under stressful conditions, suggesting an inhibiting effect of stress. The researchers suggest that this reduction of RIF under stress may pose a benefit to students in testing situations by providing access to more information held in memory (Koessler et al., 2009). I argue instead

that without RIF silencing extraneous noise, students may find themselves overwhelmed with a plethora of information and unable to locate the correct memory. While it may appear beneficial to have access to many related memory traces at once during retrieval, it could result in much more difficulty locating the specific trace one needs.

The act of forgetting is often looked upon negatively, which may lead people to view RIF as a cognitive nuisance. RIF, however, is a necessary and helpful aspect of memory (Koessler et al., 2009; Law et al., 2012). The discovery that stress inhibits RIF, whether to a student's benefit or not, highlights the severity of the impact of stress on processes of memory.

Factors that Mediate Stress-Induced Retrieval-Impairment

It is clear that academic performance can be directly impacted by the effects of stress on memory, but this unfortunate consequence does not imply students are destined to forget learned material once they encounter a stressor. In fact, studies have shown that certain personality traits as well as characteristics of the material being learned may alter the experience of stress-induced retrieval impairment.

Characteristics of the Learner

In a study by Law and colleagues (2012) a positive correlation was discovered between high extraversion scores and performance on a RIF task. Participants reporting state anxiety in combination with low extraversion experience a more clouded retrieval process and appear not to benefit from RIF. It is noted that extraversion and state anxiety have an inverse relationship, suggesting the possibility that extraverted individuals experience a generally lower stress level than introverted individuals. As such, students that are naturally extraverted may enjoy a retrieval advantage over their introverted counterparts. Further study investigating the relationship between personality and stress-induced retrieval impairment is needed, but this research offers a preliminary glimpse into the varied experiences that individuals may have under stress according to their personality traits.

Characteristics of the Information to be Remembered

Have you ever wondered why it is far easier to recall the details of a car crash or earthquake that occurred many years ago than it is to remember what you had for lunch a few days ago? You may find your answer in research that explores memory for information with differing levels of arousal. It is generally found that higher arousal of information leads to better memory representations and easier retrieval (Buchanan et al., 2006; Goldfarb et al., 2019).

In a study examining how stress influences memory, Goldfarb and colleagues (2019) manipulated both the timing of the stressor as well as the arousal level of the items. Their results demonstrate that retrieval of high-arousal information is better when stress is induced before encoding compared to when stress is absent. This may be the result of a match between arousal levels at encoding and similar cortisol representations later on during retrieval (Goldfarb et al., 2019), commonly referred to as encoding specificity (Tulving & Thomson, 1973). Other researchers have found similar results, with highly arousing words being less susceptible to stress-induced retrieval impairment (Buchanan et al., 2006). Given that some courses' subject matter is unexciting for students, this may lend an explanation for poor performance on examinations despite seemingly adequate time being allotted to study. That being said, it is unreasonable to expect all material to be arousing, and it would be more valuable to alter study habits rather than use the mundanity of studies as an excuse.

Implications for Students

Stress is an inevitable part of educational endeavors for most university students. In the above-mentioned research, many note the implications of stress in this particular setting (Gagnon et al., 2019; Karpicke & Roediger, 2008; Smith et al., 2018; Smith et al., 2016). In this final section, strategies will be presented that students can employ in order to lessen the impairment that stress may have on their academic success.

Retrieval Practice

The induction of stress renders many traditional ways of studying surprisingly inadequate. For example, students who assume that reading material in repetition is sufficient preparation for an exam may find themselves disappointed in their ability to retrieve the desired information. The remedy to improper study habits may lie in what researchers call retrieval practice (RP) as spoken of earlier, where engaging in self-testing techniques promotes more durable memories (Karpicke & Roediger, 2008; Smith et al., 2018; Smith et al., 2016). The difference in resultant performance from simply re-reading compared to RP lies in the strength of the memory that is created: Re-reading creates weak memories, whereas RP creates strong memories (Smith et al., 2018; Smith et al., 2016). Hence, studying using re-reading techniques may be satisfactory under normal conditions, but students utilizing this technique will find retrieval difficult with the induction of stress.

Students may now be wondering how many instances of retrieval will create a strong enough memory to withstand a stressful examination. Smith and colleagues (2018) explored exactly this question in their research on how RP protects memories under situations of acute stress. The authors found that a single correct retrieval attempt in the study session was enough for successful retrieval in the final recall test if the test was within 24 hours of studying. With a delay of a week between studying and testing, however, students needed at least three retrieval attempts during their study phase in order to overcome stress in the final testing phase. The authors point out that this may be why cramming for a test appears to work in the short-term but will not lead to any lasting knowledge (Smith et al., 2018).

Karpicke and Roediger (2008) investigated the effect of RP on memory performance and found similar support for the importance of self-testing in academic success. The authors recreated the typical technique of flashcard use, in which a concept is studied until one retrieval attempt is successfully executed and then is immediately eliminated from the study material. Results revealed that groups instructed to drop material after a single successful retrieval recalled a maximum of 36% when tested a week after learning, while groups that were not instructed to drop material after a single successful retrieval and instead engaged in multiple retrievals successfully recalled 80% of the learned material (Karpicke & Roediger, 2008).

The above results demonstrate a clear benefit of RP for memory, especially in stressful conditions, but how exactly this process works is still unknown. Smith and colleagues (2016) suggest that the benefit of RP may be that it promotes the establishment of numerous pathways through which to access the memory. Recall that with the induction of stress, cortisol binds to glucocorticoid receptors in the hippocampus and causes a blockage of access to the memory. The authors suggest that by engaging in RP, though, one can create alternate routes to bypass the blockages and reach the desired memory.

The strength of memories created by RP may also be explained through the lens of a levels of processing approach. In this theory, Craik and Lockhart (1972) assert that deeper consideration of the information will lead to a stronger memory, as it reaches a deeper level of processing. The act of retrieving a memory trace, as in RP, requires one to respond to a test of knowledge in a meaningful way, rather than simply re-reading in a rote memory fashion. Craik and Lockhart (1972) note that rehearsal alone is not enough to create lasting memories and that, without deeper processing, one is only delaying the forgetting of a memory. This explains why

re-reading is insufficient for later memory tests, as it accesses a much shallower level of processing and thus creates a weaker memory representation.

Conclusions

The unfortunate reality is that students will experience stress throughout their academic career, especially in post-secondary studies. Even students who recall memories with high levels of confidence are not immune to stress-induced retrieval impairment (Gagnon et al., 2019). An especially frustrating experience for students is a poor grade on an exam when a substantial amount of time was spent studying. While the unavoidable inhibiting effects of stress on retrieval likely contribute to this outcome, this is not the end of the story for students. Given what is known about stress and how it affects memory, there are strategies one can employ to provide a buffer against these adverse consequences.

As reported above, researchers have identified the ways in which stress interrupts memory processes, with stress at encoding leading to enhancement of memory formation and stress at retrieval causing a reduction of memory accessibility. With a focus on the latter: stress-induced retrieval impairment, retrieval-induced forgetting (RIF) was examined and shown to have substantial impacts on students (Law et al., 2012). A particularly interesting finding is that stress reduces the effects of RIF, which may lead students to have access to too many memories that may impede their ability to focus on relevant information (Koessler et al., 2009).

More extraverted students may reap the benefits of experiencing less anxiety and thus be less affected by stress-induced retrieval impairments (Law et al., 2012). Likewise, information that is rated as highly arousing is often retrieved with more ease than dull information (Buchanan et al., 2006; Goldfarb et al., 2019). Regrettably, personality traits and the arousal level of material are rarely factors over which students have control. As such, the best defense a student may have against the detrimental effects of stress on retrieval is through the use of proper study habits that provide a buffer against these shortcomings.

Retrieval practice (RP) is recommended by researchers as a study habit that students can adopt, should they want to improve their retrieval ability under stress (Karpicke et al., 2008; Smith et al., 2018; Smith et al., 2016). This method of repetitive self-testing has been shown to produce less retrieval errors, perhaps through the availability of multiple pathways to a single memory trace (Smith et al., 2016) or by engaging in deeper analysis of information (Craik & Lockhart, 1972).

The usefulness of RP in study practices is well documented, but what does RP look like in a practical sense? If using flashcards to study, one should continue to attempt retrieval of every card until, at the very least, three successful retrieval attempts are made. Additionally, a student may convert their class notes into questions to create a practice test and similarly ensure that at least three correct retrievals are made before moving on. It is possible that simply engaging in these practices may reduce some stress felt during the exam and lessen the overall impact on retrieval. One may also explore the concept of encoding specificity, as briefly mentioned in a previous section. As introduced by Tulving and Thomson (1973), this concept proposes that a memory is likely to be successfully retrieved in a context that is similar to that of encoding. Therefore, one could introduce a mild stressor into the study session, such as a time limit for completion of a self-made practice test, in order to mimic the stressful conditions of the actual exam. The stress felt during the study session may match the stress felt during the exam, thus providing a contextual cue to aid in retrieval. These are just a few examples of practical implications of the findings and are by no means an exhaustive list. There is room for creativity here, but the key component of study practices must be that a student is actively retrieving the information from memory, rather than simply reading or repeating it. These techniques have the potential to increase academic performance on tests and to help students become better learners overall.

Limitations of Research and Suggestions for Future Study

In the literature reviewed, measurement of salivary cortisol was used consistently, but subjective ratings were only used in research by Schwabe and Wolf (2014). This leaves a gap in the research with regard to whether or not cortisol response levels indicate the same feeling of stress in each individual. Indeed, it is possible that different cortisol elevations have varying subjective feelings, with some experiencing more anxiousness and negative affect, while others may experience a healthy level of eustress. Additionally, there is a lack of consistency in stress-induction in participants. Some researchers utilized a social stressor in the form of the Trier Social Stress Test (Koessler et al., 2009; Smith et al., 2018; Smith et al., 2016), while others used a physiological stressor in the form of the cold-pressor test (Buchanan et al., 2006; Goldfarb et al., 2019; Schwabe & Wolf, 2014). It is possible that these different forms of stress induction yield different experiences of stress. Specifically, social stressors may be more relevant when considering student stress, as physiological stress is less often experienced in the

context of examinations. This being said, neither method of stress induction exactly mimics the feeling of test anxiety. Future research may benefit from utilizing a salivary cortisol sample in combination with a subjective measure of stress, while in a naturalistic examination setting. In this way, an accurate indication of the stress students experience may be gathered, and subsequent performance analyzed in order to identify reflections of stress levels in student scores. The execution of this, however, may not be realistic, as the very act of having saliva taken may induce stress beyond that experienced organically in an examination setting.

Throughout this paper stress has been considered an inescapable construct within educational settings; however, this may not be a universal experience for students. In fact, some students may not experience a level of stress that is intense enough to cause any impairments to their performance, whereas other students may perform successfully even while in a stressed state. Further exploration into the individual differences that protect against academic stressors would benefit students greatly. In addition to improving study habits, a concept that may benefit students, but was not covered in this paper, is stress management training; if test anxiety is consistently having a negative effect on academic performance this is a technique students may wish to explore. With proper knowledge of how to overcome the impact of stress on memory retrieval, students will be better equipped to perform successfully and enjoy the process of learning.

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