Determining Cortisol's Influence on Memory Requires Future Research

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Abstract
The glucocorticoid (GC) known as cortisol is secreted from the adrenal gland when someone is exposed to stress from their internal or external environment. Cortisol modulates various physiological functions during stress to help one adapt; however, it also has an effect on cognitive functions. One cognitive function affected by cortisol, with an increasing interest among scientists, is memory. Various experiments conducted with the goal in mind of finding cortisol’s effect on memory, yield contradictory results. Some of the experiments show that cortisol weakens a person’s ability to retrieve emotional memory, and enhances their ability to retrieve neutral (Kuhlmann et al., 2005; Tollenaar et al., 2008). Others show cortisol enhances a person’s ability to retrieve emotional memory, and impairs their ability to retrieve neutral (M. Jelicic et al., 2004; P. Putman et al., 2004). This review paper focuses on analyzing these experiments and their results, to help expose methodological flaws and, as a consequence, give insight on how to improve future experiments to achieve more valid results. This collective analysis further corroborates the complex functioning of cortisol and how it affects one’s ability to recall information of varying emotional valence while undergoing different levels of stress.

Introduction
When a person is exposed to stress from their internal or external environment, glucocorticoids (GC) known as cortisol are secreted into the bloodstream from the adrenal gland. When cortisol binds to glucocorticoid receptors (GR), it helps the person adapt to stress (De Kloet et al., 1998). While cortisol modulates the physiological changes associated with adapting to stress, e.g., accelerated carbohydrate metabolism, blood pressure, and heart rate, it also affects cognitive functions (De Kloet et al., 1999; Rozendaal, 2002). Scientists are conducting experiments to find the relationship between increased cortisol and cognitive functions, and yielding variable results. Memory, for example, seems to be the most controversial. Most of the studies on cortisol’s influence on memory focus on how stress and cortisol affect emotional memory versus neutral memory. Some of the experiments show that cortisol impairs a person’s ability to retrieve emotional memory, and enhances their ability to retrieve neutral memory (Kuhlmann et al., 2005; Tollenaar et al., 2008). Others show cortisol enhances a person’s ability to retrieve emotional memory, and impairs their ability to retrieve neutral memory (M. Jelicic et al., 2004; P. Putman et al., 2004).

The experiments testing for the correlation between cortisol and memory show contradictory results, and the validity of each of these experiments is open for interpretation. These experiment’s validity need to be addressed because of the possible implications they have on causes of diseases like Alzheimer’s Disease, and Parkinson’s Disease--diseases which are suggested to be associated with hyper-cortisolism (Hartmann et al., 1996). Future, valid experiments are needed to eliminate the confusion regarding cortisol’s effect on memory. This review paper’s main focus is to compare the current experiments and their results that test for cortisol’s influence on memory and underscore the complex functioning of cortisol as it affects memory. Analyzing these experiments and their results will help to expose their flaws and, as result, give more insight on how to conduct future experiments that have valid results.

Discussion

Emotional Valence
In an experiment by M. Jelicic et al. (2004), stressed individuals showed an increased ability to recall words of high emotional valence compared to neutral words. For the experiment, 40 healthy undergraduate students, 31 women and 9 men (mean age=20.1 years (y)), participated. Participants were given an Auditory Verbal Learning Test (AVLT), which consisted of 15 emotional words and 15 neutral words that they attempted to remember. After the AVLT, 20 participants were exposed to a Trier Social Stress Test (TSST) followed by a difficult arithmetic task that lasted for 5 minutes. A TSST requires the test subject to give a 5-minute speech in front of a committee. The TSST is shown to stimulate a sense of fear and uncontrollability in the subject, as well as the cardiovascular and endocrine changes associated with stress (Dickerson and Kemeny, 2004; Kirschbaum et al., 1996).

Moreover, B. Kudielka et al. (2002) demonstrated that the resulting cortisol concentrations per
also associated with retrieval deficit. Interestingly, moderate increases in cortisol were valence retrieval overall. However, words of emotional stress and cortisol, showed impaired memory group, which experienced a significant increase in after learning the list, participants either took part given 2 minutes to learn the list. Twenty and 10 neutral words. The test subjects were which was composed of 10 positive, 10 negative, range= 19 university students (mean age=24.58±1.26 y, neutral words from memory. Nineteen male adjectives. Immediately after being exposed to the AMT, participants were told to write about a specific event that was stimulated after reading the adjective. C. Buss et al. found that subjects treated with 10 mg of hydrocortisone show significantly impaired ability to recall events. Beckwith et al. (1986) conducted an experiment that shows the effects of hydrocortisone on memory are dependent on dose, as well as duration of the memory retrieval test. Eighty male undergraduate students-whose mean age was not disclosed-from the University of
North Dakota participated and were given either 40, 20, 10, or 5 mg of hydrocortisone mixed with glucose or a capsule with just glucose. One hour following ingestion of the capsule, subjects participated in a memory retrieval test, which requires participants to read through a list of 12 neutral words. Immediately after reading through the list, subjects were cued to recall as many words as they could. Subjects were exposed to eight different lists, and thus were cued to recall from eight different lists. The 5, 10, 20, and 40 mg dosages of hydrocortisone facilitated recall of words during the first two lists. However, only the 40 mg dose enhanced recall as the experiment continued. The lowest dose, 5 mg, decreased memory retrieval as time of the experiment continued.

**Conclusion**

As expected, the experiments described above reveal indecision among researchers about the role cortisol has on memory. For example, the experiments that used TSST as a stressor show contradictory results. However, these same experiments allowed different amounts of time for consolidation, which could account for the different effects of cortisol. The experiment done by P. Putman et al (2004) yields results in line with M. Jelicic et al’s (2004); however, the methods used during the experiments were drastically different. For instance, M. Jelicic et al (2004) used the TSST to induce a stress response and measured the correlating increase in cortisol, whereas P. Putman et al (2004) did not induce a stress response in participants, nor did they measure cortisol levels as they correlate with stress. However, P. Putman et al’s (2004) experiment focused solely on individual’s abilities to locate faces of variable emotional valence—not the magnitude at which stress impairs memory retrieval.

The experiments that used hydrocortisone to increase cortisol show some positive trends. The experiment by Beckwith et al. (1986) shows the effect cortisol has when its concentration in the blood is varied, along with increasing length of a memory retrieval test, while C. Buss et al. (2004) only gave 10 mg of hydrocortisone to participants, and their memory was impaired. The two studies that are compared above, however, were performed using different types of experiments, and also performed 18 years apart from each other. So, the disciplinary context of the experiments must be considered.

In addition to variable experimental conditions, the experiments on cortisol and memory use sample sizes that are too small. To decrease variability within an experiment, it is important to use a large enough sample size. Also, most of the experiments described above include only one gender, which intuitively means the results obtained from each experiment can only apply to the corresponding experiment. Lastly, the experiments analyzed used a similar age group, young men and women, and thus the results can only apply to that age group. However, as B.M. Kudielka et al (2002) show, stress responses for young men and women correlate with similar amounts of circulating cortisol—however, during the same experiment, boys and girls (mean age = 12.1±0.3 y) had similar circulating cortisol caused by the TSST. Interestingly, in the experiment by B.M. Kudielka, older men (mean age= 67.3±1 y) experienced circulating cortisol significantly higher than younger men and women and boys and girls. Thus, future experiments should use caution when analyzing data that contain results from older men.

Regarding the experiments described above, what can be concluded about cortisol and its influence on memory is that its effect is dependent on context—in some situations it is detrimental to emotional memory retrieval and enhances our neutral memory retrieval, and in other situations the opposite pattern is seen. Since each study shows results that only apply to its experimental situation, there is not one answer to the question of what cortisol does to memory. Nevertheless, current and past researchers have provided a platform of salient results that expose the complexities underlying cortisol functioning.

**Priorities for Future Research**

To eliminate the uncertainty about cortisol’s effect on memory, future research is required. Sample sizes used in future experiments should be large enough—at the lowest, should include 100 participants. Also, the gender issue needs to be eliminated by either including both men and women in equal amounts in an experiment, or performing two identical experiments that include only men or women. Possible gender differences in the impairment effect of cortisol need to be established. Furthermore, the amount of corticosteroid binding globulin (CBG), which binds to cortisol in the blood making it inactive (Fernandez-Real et al.,1999), was not measured in any of the above experiments. However, when total cortisol is measured in the blood,
the amount of CBG-bound cortisol is included, even though it cannot bind to glucocorticoid receptors. Thus, including the amount of active cortisol versus total cortisol will increase fidelity. Nevertheless, there remains promise that future experiments will establish a reproducible pattern between cortisol and human memory.

References


