THE ATTENUATION OF THE RENEWAL EFFECT
VIA THE FORGETTING OF CONTEXTUAL ATTRIBUTES

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by

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CHAPTER I
INTRODUCTION

Since the first known attempt at a systematic measure of memory retention and forgetting by Ebbinghaus in 1913, forgetting has become a major area of modern scientific research. In his study, Ebbinghaus devised a set of trials to determine the relationship between temporal passage and normal forgetting (also known as spontaneous forgetting; see Millin & Riccio, 2004). Although later evidence suggests that the results of his particular study were confounded (e.g. due to proactive interference; McGeoch, 1942), it is still generally recognized that spontaneous forgetting and time are correlated.

However, based on McGeoch’s (1942) conclusion that time is not causal, some researchers argue that time itself does not actually cause forgetting, but rather that events which occur during a time-interval make memory retrieval more difficult (e.g. Spear & Riccio, 1994). In fact, many modern scientific investigations of memory and forgetting operate under a memory-retrieval model, which represents spontaneous forgetting as memory retrieval failure rather than interrupted or failed memory storage (e.g. Hinderliter, Webster, & Riccio, 1975; Riccio, Moody, & Millin, 2002; Briggs, Fitz, & Riccio, 2007).

Furthermore, scholars contend that the success or failure of memory retrieval (i.e. remembering or memory activation) is mediated by the presence of memory-retrieval cues, which are conceptualized as operating similarly to conditional stimuli (CS;
Hamberg & Spear, 1978; Deweer, 1986; Bouton, 1993; Spear & Riccio, 1994; Millin & Riccio, 2004; Briggs & Riccio, 2008). These retrieval cues can include any of the interoceptive (i.e. the physiological state of the subject; internal context) or exteroceptive (i.e. surrounding environment; external context) contextual attributes or features that are present during the storage of a memory (Spear, 1978; Overton, 1985; Margraf, Barlow, Clark, & Tech, 1993; Spear & Ricco, 1994; Zhou & Riccio, 1996). Under this model, memory retrieval is thought to be caused by the presence of sufficient original memory-retrieval cues in the testing environment. Conversely, spontaneous forgetting is thought to result from an absence or perceived absence of these original retrieval cues.

One important phenomenon in studies of learning, memory, and forgetting is the context-shift effect (CSE; McGeoch, 1942; Perkins & Weyant, 1958; Godden & Baddeley, 1975; Smith, 1979; Zhou & Riccio, 1996). CSE indicates that when a memory is acquired in one context (A) and then retrieval of that memory is attempted in an alternate context (B), response failure is more likely to occur. CSE has been shown to occur in both humans (e.g. Godden & Baddeley, 1975; Smith, 1979) and animals (e.g. McGeoch, 1942; Millin & Riccio, 2004). Further, there is evidence that shifts in either interoceptive (e.g. Cunningham, 1979; Bower, 1981; Share, Lisman, & Spear, 1984; Bouton, Kenney, & Rosengard, 1990) or exteroceptive (e.g. McGeoch, 1942; Godden & Baddeley, 1975; Smith, 1979; Millin & Riccio, 2004) context can result in CSE.

Since it is recognized that context is an important source of memory-retrieval cues (Spear, 1978) and CSE results in response failure, some scholars suggest that CSE, like
spontaneous forgetting, is merely another type of cue-mediated memory retrieval failure (Rosas & Bouton, 1997; Bouton, Nelson, & Rosas, 1999; Millin & Riccio, 2004). Under this interpretation, it is held that the contextual attributes which serve as memory-retrieval cues are based on the context where the memory was originally formed (A) and so all or most of those retrieval cues are naturally absent in the alternate context (B). Accordingly, this results in memory-retrieval failure and CSE when testing occurs in an alternate context.

Another important aspect of CSE is that it is time-dependent. It has been evidenced by several studies that the strength of CSE dissipates with the passage of time (e.g. Zhou & Riccio, 1996; Biedenkapp & Rudy, 2007; Wiltgen & Silva, 2007; Winocur, Moscovitch, & Sekeres, 2007). In a specific example, Zhou & Riccio (1996) found that rat subjects do not show CSE after a one or two week interval has passed between training in the original context (A) and testing in the alternate context (B). This important feature of CSE can be described as a context generalization gradient which is initially sharp (includes only context A), but flattens with the passage of time (to include other contexts, such as B; Perkins & Weyant, 1958; Riccio & Joynes, 2007). Thus, alternate contexts become capable of retrieving a memory after a sufficient time interval has elapsed following the original learning episode.

This time-mediated dissipation of CSE can be explained by what is known most commonly as the *forgetting of stimulus attributes* (Riccio, Rabinowitz, & Axelrod, 1994; Zhou & Riccio, 1996; see Riccio, Ackil, & Burch-Vernon, 1992 for review) or,
alternatively, the *forgetting of contextual attributes* (FCA used to designate both, interchangeably, hereafter; Zhou & Riccio, 1994). Importantly, the forgetting that occurs in FCA should be distinguished from spontaneous forgetting. While spontaneous forgetting occurs due to memory-retrieval failure, FCA merely represents a degradation of memory for cues that leads to contextual generalization. Accordingly, FCA is hypothetically indicated by sharp contextual generalization gradients that flatten with the passage of time, such as is the case with CSE (Riccio, Ackil, & Burch-Vernon, 1992; Riccio, Rabinowitz, & Axelrod, 1994).

There are a few notions that, when considered together, form a functional theoretical foundation for FCA. First, and in accordance with previous statements, it is held that all memory episodes contain various, independent contextual attributes which can serve as memory-retrieval cues for that episode (Reynolds, 1961; Spear & Riccio, 1994; Zhou & Riccio, 1996). Second, these contextual attributes represent some of the least persistent features of a memory; that is, can be forgotten relatively quickly as compared to other aspects of a memory, such as a target response (e.g. running, punishment avoidance; Perkins & Weyant, 1958; Spear & Riccio, 1994; Riccio, Rabinowitz, & Axelrod, 1994). Third, these contextual attributes can be forgotten at different rates, which can cause memory retrieval or responding to become differentially affected (Gisquet-Verrier, Dekeyne, & Alexinsky, 1989; Riccio, Rabinowtiz, & Axelrod, 1994). A concerted consideration of these ideas points to FCA as an explanation for contextual generalization and alternate contextual control of memory retrieval. That is,
over time FCA causes the memory for the details of the original contextual cues (A) to become degraded, setting the occasion for context discrimination failure (Ricció, Rabinowitz, & Axelrod, 1994; Zhou & Riccio, 1996). This discrimination failure, in turn, allows for contextual generalization to occur, which results in alternate contextual (e.g. context B) control of memory retrieval (McAllister & McAllister, 1963; Gisquet-Verrier & Alexinsky, 1986; Zhou & Riccio, 1994; Zhou & Riccio, 1996). Thus, since as FCA occurs a greater variety of attributes can serve as functional memory-retrieval cues, FCA is often described as a special circumstance where degraded memory (for cues) can actually lead to an increase in the memory retrieval of a response (McAllister & McAllister, 1963; Gisquet-Verrier & Alexinsky, 1986; Riccio, Rabinowitz, & Axelrod, 1994; Riccio, Millin, & Gisquet-Verrier, 2003). Importantly, however, it should be recognized that memory for either some subset or quality of those attributes must be retained in order for them to still act as functional memory-retrieval cues. The latter conceptualization can be used as an inverse indication that too great an extent of FCA might lead to failed memory retrieval altogether. One similar hypothesis is that FCA might eventually cause retrieval failure through memory-retrieval interference; that is, may lead to the retrieval of a different memory altogether (Winograd, 1968; Underwood, 1983; Riccio, Rabinowitz, & Axelrod, 1994).

Yet another key phenomenon in learning and memory is *extinction*, which is thought to serve an adaptive function for organisms; allowing them to thrive in an ever-changing environment (Bouton, 2004). Extinction, first observed by Pavlov (1927),
causes a decline in responding to the presentation of a CS, such as a context. Under a learned CS-UCS association, the UCS (e.g. shock) motivates responding to the CS (e.g. black chamber of a shuttle-box). However, after that CS-UCS association has been formed, extinction exposure—that is, sufficient presentation of the CS without the UCS—can lead to a decline in future responding to the CS. Thus, extinction is sometimes described or interpreted as memory erasure or as the disassociation of a previously formed CS-UCS relationship (e.g. Rescorla & Wagner, 1972; McClelland & Rumelhart, 1985). However, there are several phenomena that have been discovered, such as rapid reacquisition (Napier, Macrae, & Kehoe, 1992; Ricker, & Bouton, 1996), and spontaneous recovery (Pavlov, 1927), that demonstrate particular conditions under which extinguished memories (i.e. memories which have undergone extinction) can later become reactivated. These findings have, in turn, led to a general acceptance that extinction actually constitutes a type of new learning; that it leaves the original memory of the CS-UCS association intact, but conditionally decreases the probability of its future retrieval or influence on behavior (Bouton, 1993; Bouton, 2004; Briggs & Riccio, 2007).

Importantly, as classical conditioning is sometimes viewed as a mediating factor in anxiety disorder acquisition and expression (e.g. Wolpe & Rowan, 1989), extinction is also thought to play an integral role in the treatment of anxiety disorders (Marks, 1978). This indicates, however, that extinction-based psychotherapeutic treatments (e.g. systematic desensitization and exposure therapies; e.g. Choy, Y., Fyer, A.J., Lipsitz, J.D., 2006) for anxiety disorders are subject to the limitations of extinction. For instance,
spontaneous recovery, a phenomenon which is indicated by the retrieval of an original memory after extinction may analogously cause potential relapse after extinction-based psychotherapeutic treatments (for review of how spontaneous recovery and other phenomena relate to relapse see Bouton, 2002). Thus, extinction-based experiments are sometimes developed and conducted in order to identify methods for attenuating those phenomena, such as spontaneous recovery, as to improve anxiety disorder treatment efficacy (e.g. Gunther, Denniston, & Miller, 1998).

One phenomenon that operates under an extinction paradigm and which indicates potentially serious complications for extinction-based anxiety disorder treatments is the renewal effect (Bouton & Bolles, 1979; Bouton & King, 1983; Riccio, Richardson, & Ebner, 1984; Bouton & Ricker, 1994; Bouton, 2002; for review see Bouton, 2004). The renewal effect can be described as such: A response is learned in one context (A) which is followed by extinction of that response in an alternate context (B). After that, testing in the original context (A) will result in a return of responding, thus rendering the extinction treatment ineffective. Although this example of the renewal effect describes what is known as the ABA renewal design (training A; extinction B; test A; Bouton & Bolles, 1979a; Bouton & King, 1983) the renewal effect can alternatively be achieved through ABC (Bouton & Bolles, 1979a; Brooks & Bouton, 1993) and AAB designs (Bouton & Ricker, 1994; Tamai & Nakajima, 2000). Some researchers have described the renewal effect as CSE for extinction style learning (e.g. Briggs & Riccio, 2009). Additionally, similarly to CSE, the renewal effect is hypothesized to be the result of the
natural absence of the extinction context’s memory-retrieval cues in the alternate test context (Brooks & Bouton, 1993).

There have been several explicit attempts to attenuate the renewal effect, as it has been found to occur even after quite extensive extinction treatment (e.g. 84, 160 extinction trials; Gunther, Denniston, & Miller, 1998; Rauhut, Thomas, & Ayers, 2001). In fact, there have been several methods found to be successful for attenuating the renewal effect. For instance, the presentation of an extinction-predicting cue during testing (Brooks & Bouton, 1993), the use of explicitly unpaired procedures (where extinction involves the non-contingent presentation of the CS and UCS; Rauhut, Thomas, & Ayers, 2001; Thomas, Longo, & Ayers, 2005), and the transfer of contextually-based memory-retrieval cues (Briggs, Fitz, & Riccio, 2007) have all been found to be effective means for attenuating the renewal effect. Since all of these methods involve the explicit transfer or re-presentation of original retrieval cues (i.e. cue for extinction, UCS exposure, and contextual cues, respectively) in the attenuation of the renewal effect, they can be interpreted as direct support for the hypothesis that the renewal effect results from an absence of memory-retrieval cues (including contextually-based cues).

There are two other methods that have also been found to effectively attenuate the renewal effect but which appear to indicate potential problems for a memory-retrieval failure explanation of the renewal effect. However, for both there are alternative interpretations that suggest these studies can still support the retrieval failure explanation.
The first of these methods is described as a “massive” extinction procedure (Tamai & Naknjima, 2000; Denniston, Chang, & Miller, 2003). Denniston, Chang, and Miller (2003) found that 800 extinction trials (“massive extinction”) could attenuate both ABC and ABA renewal. This seems to suggest that ABA renewal can be attenuated without the direct involvement of original or test context retrieval cues during extinction. However, their method included several non-reinforced exposures to the respective test contexts between extinction trials. Although non-contingent CS presentation did not occur in these test context exposures, as it did in context B extinction, it seems plausible that some degree of extinction for the contextual cues of the test context would have still occurred due to these exposures. Thus, with their designs being essentially A[BA]A and A[BC]C (comparable to AAA and ABB designs where the renewal effect does not naturally occur) rather than ABA and ABC designs, their method actually included the explicit extinction of the test context retrieval cues.

In other studies, multiple context extinction has been found to attenuate the renewal effect (e.g. extinction in contexts B, C, D, and test in E or A to attenuate ABC or ABA renewal, respectively; Gunther, Denniston, & Miller, 1998; Chelonis, Calton, Hart, & Schachtman, 1999). Unlike massive extinction, multiple context extinction actually does appear to be a case where retrieval cues are not explicitly presented but renewal is still attenuated. However, it may be that these multiple alternate contexts (i.e. B, C, D) share, as a collective, more contextual attributes with the testing (or original, training) context than any single alternate context (i.e. B), thus increasing the potential for a
sufficient amount of individual test context retrieval cues to effectively undergo extinction. This theoretical interpretation is consistent with evidence that independent contextual attributes can control memory retrieval (Zhou & Riccio, 1996) and presumably extinction, though this latter possibility is in need of testing. Yet one might infer that, although multiple contexts may contain sufficient attributes or retrieval cues for memory retrieval as a collective, since those retrieval cues are presented separately, on independent trials (i.e. in different context exposures), the conscious activation or retrieval of a memory thus may not occur during those trials. Further, one might suppose that without this conscious activation of a memory, extinction is impossible. However, Morgan & Riccio (1994) have shown that a memory does not need to be consciously activated by retrieval cues in order for effective extinction to occur. Hence it may be the case that multiple context extinction allows for a sufficient degree of independent, contextually-based retrieval cues to be extinguished, as to permit general extinction for that memory regardless of conscious activation.

Given that the renewal effect and context shift effect (CSE) have both been evidenced to result from what appears to be a common theoretical mechanism—cue-based memory-retrieval failure—it seems plausible that treatments which may be effective for attenuating one may also be effective for attenuating the other. Accordingly, since Zhou & Riccio (1996) have found that CSE can be attenuated over a one to two week interval via FCA, it seems reasonable to hypothesize that this interval-induced forgetting of contextual attributes would also be effective for attenuating the renewal
effect at the same interval. The following study was designed to test this hypothesis, as to possibly determine another means for increasing the effectiveness of inter-contextual extinction, and also to further test the auxiliary hypotheses associated with cue-mediated memory retrieval in models of spontaneous forgetting.
CHAPTER II
METHODS

Subjects

The subjects used in this study were 69 Sprague-Dawley strain rats; 32 male and 37 female. All subjects were between 90 and 140 days old at the beginning of the experiment. All subjects were individually housed in a colony at Kent State University. The colony environment was maintained on a 15/9 hour light/dark cycle and at a constant 20°C and 24% humidity. Food and water were available *ad libitum* throughout the entirety of the experiment.

Apparatus and Contexts

Two identical, Plexiglas shuttle-boxes of the dimensions 43.18 x 17.78 x 17.78 cm were used for training, extinction, and testing. Both shuttle-boxes had false ceilings comprised of clear Plexiglas, and their floors were constructed of an electrically-conductive metal grid. The shuttle-boxes were each divided into two chambers by a guillotine door. Although the two chambers were equal in dimension, one was constructed of white walls and one of black (both opaque). The shuttle-boxes were located in two separate lab rooms which served as different contexts and each box remained in its respective room for the course of the experiment.
Context A was a 1.62 x 2.33 m room with white walls and was illuminated by fluorescent house lights. Posters were placed on the walls in order to provide visual cues novel to context A. No artificial scent or noise cues were used in context A. Context B was a 1.83 x 2.74 m room with white walls and was illuminated by a 25 watt red light bulb positioned directly above the shuttle box. Both an artificial cinnamon apple scent provided by a plug-in air freshener and white noise (75 dB) were presented to the subjects at all times in context B.

Procedures

Prior to the beginning of the experiment each subject was handled for 4-5 minutes on two separate days. A minimum of sixteen subjects, stratified for sex, were otherwise randomly assigned to each of four conditions. All subjects underwent each step of the experiment (i.e. training, extinction, testing) at the same time of day on an individual basis. Training, extinction, and testing always occurred during the light portion of the colony’s light/dark cycle. All subjects received both initial fear conditioning (training) and post-extinction testing in context A.

At training, the subjects were brought into context A and remained on the experimenter’s arm for 30 sec to provide exposure to the context. Afterward, the subjects were placed into the white chamber of the shuttle-box facing the wall opposite the closed guillotine door. After 20 sec the guillotine door was opened, allowing the subject the option of entering black chamber of the shuttle-box. The cross-latency for the
subject to enter the black chamber (all four paws) was recorded. Upon the subject’s entering the black chamber, the guillotine door was lowered. Two inescapable 1 sec foot-shocks (0.5 mA) were delivered at 10 and 15 sec after the door was closed. Ten seconds after the final foot-shock, the subject was removed from the black chamber and immediately returned to the colony.

Twenty-four hours after training, two of the condition groups received extinction treatment. One group received extinction in the same context, A (1-Sm) and the other group received extinction in the shifted context, B (1-Sh). Before extinction, each subject was brought into its extinction context (A or B) where it remained on the experimenter’s arm for 30 sec to provide context exposure. After that, the subject underwent extinction. Extinction consisted of a forced, 20 min exposure to the black chamber of the respective context’s shuttle-box. Following the extinction exposure, the subject was removed from the shuttle-box and immediately returned to the colony. Fourteen days after training, the other two condition groups (14-Sm, and 14-Sh) underwent an identical extinction procedure; 14-Sm in context A, and 14-Sh in context B.

Testing occurred twenty-four hours after extinction for all subjects. Testing took place in context A and was procedurally identical for all condition groups. Before test, each subject was again given a 30 sec exposure to the test context (A) while on the experimenter’s arm. At test, the subject was placed into the white chamber of the shuttle box facing away from the closed guillotine door. After 20 sec the guillotine door was raised and remained open for the remainder of the test, as to allow the subject to freely
move between the chambers. The subject’s initial cross-latency to the black chamber (all four paws) and the total time spent in the white chamber (TTW) over a 10 min interval were recorded as dependent measures. If a subject did not cross into the black chamber within the 10 min interval, the maximum time was recorded (10 min; 600 sec) for both measures. After testing, all subjects were immediately returned to the colony.
CHAPTER III
PRELIMINARY ANALYSES

Convergent Validity: Total Time on White (TTW) and Test Latency

Since this study utilized two dependent variables (test latency, and the total time on white or TTW), both of which were intended to measure the same construct (fear), a preliminary analysis was run in order to determine their convergent validity. Given that both of these measures are intended to indicate extent of passive avoidance and expression of learned fear, their relationship was hypothesized to be strong. Due to ceiling effects, all subjects that exhibited the maximum test latency (600 sec) and thus did not have the opportunity to score less than 600 sec on TTW were excluded from these preliminary analyses (n = 36).

In a first attempt to discover the relationship between test latency and TTW, a Pearson product-movement correlation comparing the two was run for all remaining subjects (n = 33). A strong correlation was found (r = 0.78, p < 0.01; see Figure 1). This approach, however, contained a serious confound: TTW includes all of the time on the white side before the initial cross at test (test latency), plus any extra time on white (ETW) after the initial cross. Since TTW includes test latency in its scoring, their calculated correlation was naturally very strong.
In order to remove test latency from TTW, the ETW for each individual subject was calculated (ETW = TTW – test latency). However, the inter-subject variability in test latency scores meant that the subjects had varying ranges ($R = 45 - 575.12$ sec) of total extra time (TET = 600 – test latency; total time after the initial cross): time in which they had the opportunity to score on ETW. Varying TET scores would not permit a proper comparative analysis of differences on ETW scores. In order to equalize TET scores and draw comparisons between ETW scores, the following formula was used to calculate the percent of extra time on white (PETW) for each individual subject:

$$\frac{(TTW - Test\ Latency)}{(600\ sec - Test\ Latency)} = \frac{Extra\ Time\ on\ White\ (ETW)}{Total\ Extra\ Time\ (TET)} = PETW$$
So as to permit the examination of the possible non-linear relationship between ETW and TET that was implied by the distribution of TTW and test latency scores in Figure 1, four subjects which exhibited 0 ETW were removed from the sample for the remainder of the preliminary analyses.

Another Pearson product-movement correlation was run comparing test latency with PETW. A moderately strong correlation was found \( n = 29; r = 0.38, p < 0.05; \) see Figure 2). Although this result suggests that a moderately strong relationship exists between ETW and test latency, even after control for the variation in TET scores, it appears that factors other than expressed fear demonstrate a strong influence on one or both of these measures.
It may be the case that the range in TET causally influenced ETW scores, in turn affecting PETW and biasing this analysis. Furthermore, due to the small condition sizes that resulted from the reduced overall sample in these preliminary analyses, further analyses could not be effectively run in attempt to control for any differential effects of the manipulated variables (e.g. context, interval) on PETW and test latency, and so these preliminary results should be interpreted with caution. Regardless, what appears to be a moderately strong convergent validity between ETW and test latency in this case suggests that both are independent and likely satisfactory measures of fear for the purposes of this study. Unfortunately, due to the reduced condition sizes resulting from the necessary removal of subjects which had 0 TET (i.e. 600 TTW), PETW could not be effectively used as a dependent measure in the results of this study. Instead, the traditional TTW measure was employed.

**Initial Cross Latency at Training**

A one-way ANOVA revealed that there were no significant differences between conditions for initial cross latency at training \((n = 69; F(3,65) = 0.80; p = 0.50; M = 32.24 \text{ sec}; SD = 47.79 \text{ sec})\). That there was no significant difference between conditions for initial cross latency at training supports the auxiliary hypothesis that any differences on the dependent measures between conditions are due to training effects and independent variable manipulation.
CHAPTER IV
RESULTS

Test Latency

A two-way ANOVA, with subject sex controlled for as a covariate (F(1,64) = 1.90; \( p = 0.173 \)), was run to test for differences in test latency by context and interval (\( n = 69 \)). The ANOVA revealed no significant main effects on test latency by context (F(1,64) = 1.59; \( p = 0.21 \)) or interval (F(1,64) = 1.20; \( p = 0.28 \)). Furthermore, no significant interaction effect between context and interval was found to influence test latency scores (F(1,64) = 2.18; \( p = 0.15 \); see Figure 3).

Test Latency by Condition. Notes: Based on condition means. Error bars denote 95% confidence interval. All depicted values in the above figure are adjusted for subject sex as a covariate; evaluated at the following value: Subject sex = 1.54.
Test Latency and Subject Sex

Another ANOVA was run to identify how subject sex influenced scores for test latency. The ANOVA revealed that there was no main effect of sex on test latency scores ($F(1,61) = 1.72; p = 0.19$). There were also no significant interaction effects between sex and context ($F(1,61) = 0.02; p = 0.89$) or sex and interval ($F(1,61) = 1.64; p = 0.21$) on test latency scores. However, a marginally significant three-way interaction between sex, context, and interval on test latency scores was found ($F(1,61) = 3.62; p = 0.06$; see Figure 4).

Test Latency by Subject Sex and Condition. Notes: Based on condition means. Error bars denote 95% confidence interval.
**Total Time on White (TTW)**

Another two-way ANOVA, again with subject sex controlled for as a covariate (F(1,64) = 0.03; \(p = 0.87\)), was run to test for differences in total time on white (TTW) by context and interval (\(n = 69\)). The ANOVA revealed that there were no significant main effects on TTW by context (F(1,64) = 0.38; \(p = 0.54\)) or interval (F(1,64) = 1.90; \(p = 0.17\)). A marginally significant interaction effect between context and interval on TTW was found (F(1,64) = 3.00; \(p = 0.09\); partial \(\eta^2 = 0.33\); see Figure 5 for a graphical depiction of the interaction between context and interval; see Figure 6 for adjusted mean TTW scores by condition).

![Figure 5](image)

*TTW by Context and Interval. Notes: Based on condition means. All depicted values in the above figure are adjusted for subject sex as a covariate; evaluated at the following value: Subject sex = 1.54. Interaction \(p = 0.09\); partial \(\eta^2 = 0.33\).*
**TTW by Condition.** Notes: Based on condition means. Error bars denote 95% confidence interval. All depicted values in the above figure are adjusted for subject sex as a covariate; evaluated at the following value: Subject sex = 1.54.

**Total Time on White (TTW) and Subject Sex**

Another ANOVA was run to identify how subject sex influenced scores for total time on white (TTW). The ANOVA revealed no main effect of sex on TTW scores (F(1,61) = 0.07; p = 0.80). There were no significant interaction effects between sex and context (F(1,61) = 0.03; p = 0.96) or sex and interval on TTW scores (F(1,61) = 0.14; p = 0.71). However, a significant interaction between sex, context, and interval on TTW scores was found (F(1,61) = 5.35; p = 0.24; see Figure 7).
TTW by Subject Sex and Condition. Notes: Based on condition means. Error bars denote 95% confidence interval.

Importantly, a Bonferroni correction, given the use of two dependent variables in this study ($\alpha/n = 0.05/2 = 0.025$ significance level for $p$), applies and so these results should be interpreted with the utmost caution.
CHAPTER V
DISCUSSION

This experiment was designed in order to examine the possibility that the renewal effect could be attenuated by permitting the forgetting of contextual attributes (FCA) to occur over a two week interval between training and extinction. As no significant differences between conditions were found and total time on white (TTW) and cross latencies remained high at test, it is impossible to determine based on these results whether FCA can be effectively used to attenuate the renewal effect.

The results of this experiment seem to indicate that extinction did not effectively occur under either normal or manipulated conditions, preventing further evidence-based analyses of FCA and the renewal effect. There are two probable explanations for why extinction did not effectively occur in this study. First, since testing took place 24 hrs after the extinction treatment, it may have been the case that spontaneous recovery (Pavlov, 1927) occurred. Spontaneous recovery is a phenomenon where a return in responding occurs following an interval between extinction and testing, such as the one day interval utilized in this study. This could be avoided in future experiments by testing immediately after extinction. Second, it may simply be the case that the implemented extinction exposure duration was insufficient for achieving effective extinction. This problem could be avoided in future experiments by increasing the extinction exposure
duration used. Either of these explanations could account for why TTW and cross latencies at testing remained high across all conditions in this study.

Convergent Validity: Extra Time on White (ETW) and Test Latency

Preliminary analyses in this study indicated that there may be at least a moderately strong correlation between test latency and extra time on white (ETW) as dependent variables measuring fear, but with results which were unavoidably subject to several extraneous variables. In order to determine whether ETW and test latency are both effective at measuring the same construct (fear), and thus to strengthen results or to identify potentially ineffective measures, future studies should be conducted to more precisely investigate the convergent validity between ETW and test latency.

Absolute vs. Relative Measurement of Extra Time on White (ETW)

Following the difficulties of determining the convergent validity of test latency and total time on white (TTW) in this project, the question arose whether it is more effective to measure the extra time on white (ETW) at an interval relative to test latency (i.e. where possible total extra time or TET range = 600 sec – test latency) or to equalize the opportunity for subjects to freely choose between the shuttle-box chambers after the initial cross at testing with use of an absolute TET interval (i.e. test latency + x seconds for TET). Considering the unaccounted-for variables that seem to be indicated by the relative weakness of the correlation between test latency and the percent of extra time on
white (PETW) in this study \( r = 0.38, p < 0.05 \), and that an logarithmic regression between TET and ETW accounts for slightly more variability \( R^2 = 0.47 \) than a linear model \( R^2 = 0.43 \) in the current sample (see Figure 8), the absolute TET design seems to involve fewer extraneous variables than the alternative. However, the superior fit of the logarithmic regression may simply be the result of chance variation in the sample. Furthermore, the current results may be confounded by uncontrolled factors in this analysis (i.e. context, interval). Thus, future studies should be conducted to investigate the relationship between TET and ETW and how that relationship may differentially affect ETW scores that are measured relative to test latency.

**Figure 8**

**ETW and TET. Notes:** *Linear Regression:* \( y = 1.107+113.1; R^2 = 0.43 \). *Logarithmic Regression:* \( y = 98.85\ln(x)-381.9; R^2 = 0.47 \).
The Time-Dependence of Extinction

Spontaneous recovery aside, the notion that different extinction durations may render extinction as more or less effective seems to entail an extinction-moderating process that is not explicitly identified. Consider, for instance, the question of what duration is effective for extinction and, other than time, what makes that duration characteristically different from another, ineffective duration? Certainly one would think that an extinction exposure where a feared UCS is never presented should on some level indicate safety, regardless of the exposure’s duration. Further, the notion that extinction exposure duration itself, rather than a phenomenon that is simply correlated with time, is a conditional feature of effective extinction seems to indirectly challenge all of cue-based memory-retrieval theory. If time is a necessary, causal component of effective extinction, then the argument that time is not a necessary, causal component of spontaneous forgetting becomes much less compelling. In any event, however, this interpretation of time as a causal factor seems implausible (e.g. McGeoch, 1942), which suggests that there must be some other, underlying component to extinction that has yet to be explicitly identified but which shares a functional relationship with the extinction exposure duration. If possible, future studies should be conducted to investigate the process and function of this unknown phenomenon that seems to moderate extinction.
Population

The sample used in this study was 69 Sprague-Dawley strain rats. Different results might be obtained with the use of a different population, as extinction, the forgetting of contextual attributes, or the renewal effect may occur or manifest differently in alternate populations.

The Forgetting of Contextual Attributes (FCA) Interval

In this study, a time-interval of 14 days was used to mediate the forgetting of contextual attributes (FCA) between training and extinction. It is possible that the use of a longer interval could permit a greater extent of FCA, making effective extinction in the alternate context more likely. In addition, if this study were to be replicated, the use of a series of different intervals (i.e. three or more) between training and extinction would strengthen our understanding of the relationships between time, FCA, and the renewal effect.

The Interaction of the Forgetting of Contextual Attributes (FCA) with Context Shifts

Since there have been few studies that have investigated how the forgetting of contextual attributes (FCA) interacts with shifted contexts (e.g. Zhou & Riccio, 1996), and seemingly none on FCA and the renewal effect, much of FCA’s function in this regard is left to speculation. Had extinction proved effective in this study, the results would have shed light on this matter. As it stands, however, and with the methodology
and hypothesis used in this study, there seem to be at least three possible ways in which even effectively produced FCA could interact with context shifts to produce a null result when testing occurs in the original context: 1) dissipation of the effects of FCA upon re-exposure to the original context’s attributes or cues, 2) FCA causes complete alternate contextual control of the original memory’s retrieval, or 3) FCA causes only an insufficient number of independent attributes to undergo extinction.

In the first case, one might hypothesize that the generalization effects of FCA can be removed with re-exposure to the original memory-retrieval cues. This possibility is in line with the fact that context re-exposure has been found to reduce contextual generalization (e.g. Zhou & Riccio, 1994; Wiltgen & Silva, 2007). Should this be the case, it would be unlikely that FCA is effective for attenuating ABA design renewal unless the original cues from context A were forgotten more extensively (i.e. over a longer interval) before re-exposure to them at testing.

In the second case, it may be that FCA does in fact permit an alternate context to control a memory’s retrieval and thus extinction. However, under certain methodological designs, such as the one employed in this study, this could result in AAB renewal or CSE for extinction. For example, in this study it was hypothesized that due to FCA a subject would more or less perceive (on some level) that context B is context A after a long interval, allowing context B to control memory retrieval and permit extinction. Even if that were the case, however, a re-exposure to context A after only a short, 24 hr interval following extinction could lead a subject to perceive context A as an entirely different
context altogether at testing; inviting the occurrence of AAB renewal or CSE for extinction.

For the two preceding reasons, it appears that a more effective experimental design to test the current study’s hypothesis that FCA can attenuate the renewal effect would include an extinction-test interval that permits the re-occurrence of FCA between extinction and testing. This would decrease the likelihood of sharpening the contextual generalization gradient upon re-exposure to the original context (A) and also help to prevent the FCA-mediated AAB renewal or CSE for extinction that could result from the use of a short interval between extinction and testing. Such a design, however, would still open itself up to the possibility of spontaneous recovery.

Third and finally, even if FCA did permit effective extinction of attribute-type cues in the alternate context (B) and that extinction did in fact transfer back to the test context (A), it may be the case that these extinguished cues were insufficient for producing expressed extinction in context A due to other, non-extinguished retrieval cues. To illustrate this idea, suppose that there are a total of five (\(v, w, x, y, \text{ and } z\)) contextual attributes in context A. It may be that of these cues, \(v, w, \text{ and } x\) are effectively extinguished in the alternate context via FCA. However, at testing, the non-extinguished cues \(y\) and \(z\) may be sufficient, either singly or potentially by their simultaneous moderation of the fear-meaning of cues \(v, w, \text{ and } x\), for producing original memory retrieval and the renewal effect. This does lead one to wonder: what is the relationship between the proportion and the memory-retrieving strength of any original cues that are
extinguished and the effectiveness of that extinction at re-exposure to some or all of that memory’s original retrieval cues?

Furthermore, this overall notion of insufficient independent cue extinction can be interpreted in at least two ways. First, it may be the case that there are simply no approximations of cues $y$ and $z$ in context B, and so regardless of FCA they are never explicitly extinguished. Second, some scholars argue that individual attribute-type contextual cues are forgotten at different rates (e.g. Spear & Riccio, 1994), and so while a particular extent of FCA may be sufficient for the generalization of cues $v$, $w$, and $x$ to cues in context B, that same extent of FCA may not be sufficient for achieving the generalization of cues $y$ and $z$. In any event, future studies should be conducted to provide insight to the functioning of FCA under conditions of context shift.

**Conclusion**

Future studies should be conducted to test the hypothesis that the forgetting of contextual attributes (FCA) can attenuate the renewal effect. Though the results of this study were null, likely due to methodological or procedural issues which resulted in an insufficient degree of extinction, the study led to the identification of several potential topics for future research: the convergent validity of extra time on white (ETW) and test latency, the effectuality of measuring ETW with test latency-relative versus absolute designs, and the identification of a possible underlying and undefined mechanism of extinction. Furthermore, some possibilities of how FCA may interact with context shifts
were described and may help guide researchers in future investigations of this interesting phenomenon.
REFERENCES


