THE DETECTION OF STIMULUS BIAS AND
THE ROLE OF COUNTERFACTUAL THINKING

BY

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A Thesis Submitted to the Graduate Faculty of
WAKE FOREST UNIVERSITY GRADUATE SCHOOL OF ARTS AND SCIENCES
in Partial Fulfillment of the Requirements
for the Degree of
MASTER OF ARTS
Psychology
May, 2015
Winston-Salem, North Carolina

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I would first like to thank my advisor, Dr. John Petrocelli, for being a supportive, insightful, responsive, and most of all an immensely helpful presence in my life for the past two years. I would not be where I am today without his guidance. I would also like to thank Dr. Eric Stone and Dr. Cathy Seta for serving on my committees and providing consistently useful feedback throughout this multi-year process. I would like to thank Dr. Allan Louden for serving on my thesis committee. I would also like to thank Tai Hensley, Nicole Berlin, Olivia LaMonte, and Emily Stagnaro for serving as research assistants during crunch time; without their help, there would be no thesis. I would like to thank Janice Jennings and Teresa Hill, who are always warm, supportive, and helpful.

I would like to thank my family for being supportive, as they always are; my friends, for providing critical support services like food and laughter; and Annie, for being my rock.
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ABSTRACT

When attempting to learn probabilities and covariations between causes and effects from experience, people experience a surprising deficit in turning repeated exposures of a stimulus into knowledge of the stimulus’ pattern. People fail to detect even perfect cause-effect relationships as such. The current study tested counterfactual thinking (i.e., mentally simulating alternatives to reality) as a potential mechanism underlying this deficit in learning by manipulating the participation level of the participants (observation vs. prediction). It is proposed that counterfactual thoughts interfere with the memory of the repeated exposures of cause-effect relationships and therefore inhibit experiential learning itself. The current study also attempted to demonstrate the role of cognitive load in this phenomenon. A significant effect of Task Role (observers vs. predictors) was found for both counterfactual generation and bias detection. Findings are discussed in light of learning theory, future research directions, and applied implications.
INTRODUCTION

What are the fundamental systems underlying human decision-making? What are the necessary elements without which people would be paralyzed by indecision, unable to choose among the paths laid before them? While there are almost certainly no definitive answers to such broad questions, one element that is certainly an important component to the process of decision-making is the knowledge gained from experiential learning (Gershman, Markman, & Otto, 2014; Yechiam & Busemeyer, 2005). Presumably, people use the information they gain from events they experience throughout their lives as the building blocks of their decision-making process (e.g., Ariel, 2013; Bohil & Wismer, 2014; Collins, Percy, Smith, & Kruschke, 2011). Without the ability to call on the knowledge gained through experience, one’s ability to choose would be severely compromised.

However, there is a surprising learning deficiency commonly found in a particular type of experiential learning situation. Individuals who are exposed to repeated trials of a simple stimulus, and who are then asked to draw conclusions based on their learning of that stimulus, do not fare as well as intuition would suggest (Petrocelli & Harris, 2011; Petrocelli, Seta, & Seta, 2013). A phenomenon that has been noted in the literature is that people are more sensitive to contingency information when it is presented in summary (e.g., organized in a table) than when it is presented via exposure to the information in the form of repeated trials or exposures (Kao & Wasserman, 1993; Ward & Jenkins, 1965). However, in the real world, information is rarely presented in summary format; instead, learning the associations between events, situational features, or stimuli can often only be acquired through experiencing or witnessing their covariation. Yet it is this very format
which appears to hinder individuals from acquiring experiential knowledge relative to summary information.

The failure to sufficiently learn associations between events and outcomes via repeated trials was most clearly demonstrated in a study that asked participants to judge the causal nature of the relationship between pressing a telegraph key and the illumination of a light (Wasserman, Elek, Chatlosh, & Baker, 1993). The researchers altered both the probability of the cause being followed by the effect (i.e., “P(E|C)”) and the probability of the effect appearing without the prior cause (i.e., “P(E|~C)”). Each P(E|C) was crossed with each P(E|~C), resulting in 25 between-subjects conditions. After observing several trials of the key press (or lack thereof) and the illumination of a light (or lack thereof), participants were asked to judge causality using a -100 to +100 scale, whereby -100 represented a perfect preventative causal relationship (the telegraph key always prevented the light from illuminating) and with +100 representing a perfect generative causal relationship (the telegraph key always illuminated the light).

Wasserman et al. (1993) found that participants’ ratings of causality generally mapped on to how powerful the relationships were (e.g., when the key had a 50% chance of illuminating the light and the light had a 50% chance of illuminating without a key press, they rated the situation as very low in causality relative to a 75%-0% contingency). However, what is most noteworthy about the findings is that the researchers never observed a point at which the participants were 100% certain of the causality. Even when the light illuminated on every trial a participant pressed the key (P(E|C) = 1) and the light never illuminated when the key wasn’t pressed (P(E|~C) = 0), the participants rated the causality as .85 – a full .15 shy of the perfect causality they witnessed. Likewise, when
the light always illuminated when they didn’t press the key and never illuminated when they did, they rated the causality as -0.75 – this time, 0.25 shy of the perfect causality they witnessed.

These findings suggest that perceptions of probabilities of events, built on repetitive observation over time, are somehow distorted, making it difficult to perceive even perfect causality. Wasserman et al.’s (1993) findings also suggest that perceptions of causality quickly become even more distorted as the situation becomes more muddled – when $P(E|\sim C)$ was increased to 0.25, meaning that the light illuminated 25% of the time even when the participants did not press the key ($P(E|\sim C) = 0.25$), and illuminated every time they did press it ($P(E|C) = 1$), the causality rating dropped to 0.52. People, therefore, have difficulty determining with accuracy the relationship between events by experiencing them as repeated trials.

A related example, and one that further specifies the nature of this experiential learning deficit, involves how people interact with a biased die. Newell and Rakow’s (2007) participants either witnessed a biased die being rolled or received hands-on experience by participating in the rolling themselves. Participants were then given the opportunity to predict future die rolls. The researchers discovered that those who had hands-on experience performed worse on subsequent prediction trials concerning the biased die than those who had simply observed the die. That is, participants who rolled the die were less likely than their counterparts to adopt the optimal strategy (i.e., universally predicting the obvious and most likely outcome). Newell and Rakow’s findings add another element to the experiential learning deficit previously discussed – active participation in the repeated trials further decreased the ability of the participants
to successfully learn the probabilities involved in the trials. Not only do people fail to
learn from repeated exposures to cause and effect relationships as well as would be
expected, but the more trials they experience, the worse their learning appears to be.
Newell and Rakow attributed this experiential learning malfunction to a memory event –
those who participated in the die rolling tried to mentally conform their future strategies
to what they remembered instead of the actual optimal strategy.

The problem with experiential learning, described here, is further highlighted by
the study of how people infer causation and covariation. This research has also revealed
less-than-optimal associative learning from trial-by-trial series studies (see: Kao &
Wasserman, 1993; Lober & Shanks, 2000; Shanks, 2004; Ward & Jenkins, 1965;
Wasserman et al., 1993). If memory interference underlies the repeated-trial experiential
learning deficit, an investigation into what might be causing such a memory deficit is
warranted.

**Counterfactual Thinking**

I propose that a potential cause for the repeated-trial experiential learning
deficiency is counterfactual thinking. Counterfactual thoughts are post-hoc,
spontaneously-generated mental simulations of alternatives to reality (Byrne, 2005;
Kahneman & Tversky, 1982; Markman, Gavanski, Sherman, & McMullen, 1993; Roese,
1997). Counterfactual statements have a tendency to take the form of an “if only…then…”
structure, in which an alternate precursor to an event is mentally simulated, which is then
followed by a mental simulation of an alternate outcome. Counterfactual thoughts can be
“upward” (i.e., mental simulations that are better than reality) or “downward” (i.e.,
mental simulations that are worse than reality; Markman et al., 1993). The most
frequently studied counterfactual thoughts are upward, because people tend to be motivated to mentally undo undesirable outcomes and refrain from mentally undoing desirable outcomes by taking them at face value (Gilovich, 1983). However, there are a variety of different types of counterfactual thinking that are beyond the scope of the current research (see: Epstude & Roese, 2008; Markman & McMullen, 2003).

Counterfactual thoughts are also a ubiquitous part of life – research shows that they are generated regularly and throughout an individuals’ life (Landman & Manis, 1992).

What is the connection between counterfactual thinking and learning? It is intuitive to expect counterfactual thoughts to enhance learning. In fact, a functional view of counterfactual thinking was endorsed by earlier accounts (Markman et al., 1993; Roese, 1997). Counterfactual thoughts seem to create prescribed behavioral changes for the future. They are believed to help identify cause-effect, or if-then, relationships, and they are believed to aid planning behavior. However, consistent with research suggesting that counterfactuals can have a deleterious effect on memory and learning (Petrocelli & Crysel, 2009; Petrocelli & Harris, 2011; Petrocelli et al., 2013), here it is proposed that counterfactuals may lead to a repeated-trial experiential learning deficit due to their impact on memory.

The first indication that counterfactuals can be dysfunctional in nature – although not addressed explicitly – can be inferred from the results of a study conducted by Gilovich (1983). Gilovich investigated how and why gamblers continue to gamble even when they lose. His research showed that people tend to discount their losses more than their wins – their wins are taken at face value, but their losses are viewed as “near wins.” One way in which participants do this is by explaining away losses using counterfactual
thoughts. By engaging in counterfactual thinking along the lines of “If I hadn’t stayed in, I wouldn’t have lost the money,” or “If that player hadn’t taken my card, I would have won,” gamblers usually have little intention to discontinue gambling (Petrocelli & Crysel, 2009). Thus, it may be concluded that counterfactual thoughts are non-beneficial and actually harmful to the individuals generating them.

Sherman and McConnell (1995) explicitly addressed the possibility that counterfactual thoughts might have negative consequences. They discussed several ways in which counterfactual thoughts could produce negative outcomes as well as positive ones, and described several studies that supported their claims. Following Sherman and McConnell’s review, more research attention has been paid to further clarifying the processes through which counterfactuals may be dysfunctional. For instance, Petrocelli and Harris (2011) examined decision behavior and counterfactual thinking in the context of the Monty Hall Problem. The Monty Hall problem places a decision maker in a situation in which one of three doors has a desirable prize behind it, and asks him/her to choose one; one of the non-selected doors is opened to reveal that it did not have the prize behind it. The decision maker is then asked to either switch to the remaining door or to stick with his/her previously-selected door. The correct action is to switch, because there is a 2/3 chance that the initially non-selected door will have the prize while only a 1/3 chance that previously selected door will have the prize. Petrocelli and Harris showed that repeated trials did not increase performance on a task, and that the more counterfactuals that were generated, the less success individuals had in learning the concept rule necessary for maximizing performance. Indeed, the Monty Hall problem is one in which participants are often stubborn in their tendency to persist using suboptimal
strategies. Specifically, Petrocelli and Harris showed that switch-losses (in which the correct strategy leads to a loss) lead to a greater frequency of counterfactual thoughts than stick-losses (in which the incorrect strategy leads to a loss), and that counterfactualized switch-losses were negatively associated with improvement on the task (i.e., learning as evidenced by subsequent switch-decisions).

Another study conducted by Petrocelli, Seta, Seta, and Prince (2012) showed that the increased generation of counterfactual thoughts can lead to worse performance on future academic tests. Furthermore, this relationship was mediated by studying behavior: those who generated counterfactual thoughts were less likely to study. It was reasoned that these relationships were the result of reduced perceived need to study by mentally simulating any need for it away with counterfactual thoughts. Other research (Petrocelli et al., 2013) also showed a repeated-trial learning deficit linked to counterfactual thoughts. Participants were asked to judge fictitious stock performances that followed a simple and predictable pattern, of which the participants were not explicitly informed; the participants who spontaneously generated counterfactuals were less likely to discover the simple pattern of outcomes (i.e., 40 trials of A, B, A, B, A, B…). In another study, those who were asked to generate counterfactuals following repeated trials were also less likely to notice the pattern than were their counterparts who were asked to list the first thoughts that came to mind. A memory interference process was theorized to underlie the link between counterfactuals and experiential learning.

The memory trace interference underlying the theory of dysfunctional counterfactual thoughts is made more explicit by Petrocelli and Crysel’s (2009) report, which elucidates the “counterfactual inflation hypothesis.” They reported that the
production of counterfactual thoughts led to inflating the number of blackjack wins players had actually experienced. Thus, the actual act of generating counterfactuals can lead to distortions in memory. Essentially, as they form memory representations of reality, people appear to also store representations of alternatives to reality, which appear to distort their personal versions of reality. This distortion has important consequences for downstream decision-making.

There is also other evidence that there is a strong connection between counterfactual thoughts and memory formation about daily life experiences; the evidence tends to indicate that counterfactual thoughts are memory interferers. De Brigard, Szpunar, and Schacter (2013) reported that counterfactual thought repetition leads to an increase in clarity and vividness of the alternative being imagined and ultimately leads people to judge the alternatives as less plausible. However, it seems possible that the increased clarity of the alternative event can detract from the clarity of the real event. Another study, conducted by Ferrante, Girotto, Stragà, and Walsh (2013), showed that counterfactual thoughts are not inhibited by realistic expectations the way that real events are; this infeasible alternative, clarified by repeated counterfactual thought generation, could lead to poor decision-making when it suggests an action that does not actually work in reality. Finally, most explicitly, it was found that memory recall of events about which counterfactuals were generated was interfered with by the counterfactuals themselves (Gerlach, Dornblaser, & Schacter, 2014).

**Functional view of counterfactual thoughts.** Thus far, I have considered the dysfunctional possibilities of counterfactuals thoughts. However, a functional view of counterfactual thoughts contends that counterfactuals serve the primary purpose of
enabling improved performance on future tasks (see: Epstude & Roese, 2008; Markman et al., 1993; Roese, 1997). The primary positions of the functional view of counterfactual thoughts were described by Epstude and Roese (2008), who elucidated a pathway and mechanism behind the functional theory. Their theory is comprised primarily of two parts: the “content-specific” pathway and the “content-neutral” pathway. The content-specific pathway closely resembles the intuitive way that many might imagine as the mechanism behind counterfactual thoughts leading to positive changes in behavior. Problems generate upward counterfactual thoughts (“I should have done X.”), these thoughts generate intentions (“I should do X.”), and the behavior is then carried out in the future. This is called the content-specific pathway because the final change in behavior is identical to the content of the initially generated counterfactual thought; the content of that counterfactual thought is carried through to the action (Epstude & Roese, 2008).

The content-neutral pathway uses several potential mechanisms, all of which are indirect. It is described as content-neutral because instead of an explicit counterfactual causing the action it focuses on, the act of counterfactual generation in general is the causative force underlying the eventual positive behavior. Epstude and Roese (2008) proposed three mechanisms behind this indirect route: mindsets, motives, and self-inference. In the mindset pathway, the generation of counterfactuals puts an individual into a mode of thinking that features “attention shifts to specific classes of information and the use of specific inferential strategies” (Epstude & Roese, 2008, p. 175). In the motivation pathway, the negative affect associated with upward counterfactual thoughts serves as a motivating tool to improve behavior. In the self-inference pathway, the generation of a counterfactual changes the way and individual perceives him/herself,
giving him/her a higher degree of perceived control that then enhances the likelihood of performing the positive behavior. Epstude and Roese (2008) hypothesized that the content-neutral and content-specific pathways work simultaneously, with feedback between the two systems, and both leading to the positive change in behavior.

Further research has clarified and refined Epstude and Roese’s (2008) functional theory and the potential benefits of counterfactual thoughts in general. For instance, Myers, McCrea, and Tyser (2014) found that when the negative affect generated from upward counterfactual thoughts was attributed to another cause other than the mental image of the initial failure, behavior did not improve in the way that the content-specific pathway would predict. They concluded that the content-neutral pathway, therefore, was much more robust and was the primary motivator behind the change in action caused by the generation of counterfactuals.

Another study, conducted by Nasco and Marsh (1999), found support for the self-inference portion of the content-neutral pathway, showing that higher perception of control resulted in better grades on tests. When differentiating upward counterfactuals further into additive (“I wish I had”) versus subtractive (“I wish I had not”), it was found that additive counterfactual thoughts specifically improved future performance on a negotiation task (Kray, Galinsky, & Markman, 2009). They explained this phenomenon using both the content-specific pathway (additive counterfactual thoughts are conducive to more creative and specific plans of action) and the content-neutral pathway (additive counterfactual thoughts promote regulatory focus, which leads to better negotiation performance). In addition, Markman et al. (1993) argued that while downward
counterfactual thoughts were comforting, upward counterfactual thoughts might prepare the individual for the future.

This functional view of counterfactuals has both its merits and its empirical support. In particular, there seems to be some support for the mechanism of the content-neutral pathway, in which ancillary effects from the generation of counterfactual thoughts cause beneficial behavioral change. However, one of the focuses of the current investigation of counterfactuals is missing from these accounts of the effect of counterfactual thoughts – memory, and the possibility that counterfactual thoughts mediate the connection between experiential learning and memory and decision-making. If counterfactuals influence behavior as described by the functional theory, then there should be no repeated-trial experiential learning deficit. That is, the more exposure to a stimulus or environment a person receives, the more the functional counterfactuals should be, and the more learning should be facilitated. However, a dysfunctional view of counterfactuals would make a very different prediction. That is, under the dysfunctional model, the sheer volume of counterfactuals generated by a repeated trial paradigm would serve to obscure the true nature of any associations, and thus lead to the noted repeated-trial experiential learning deficit.

**Pilot Study**

The present research was designed as an iteration and advance of prior research conducted by Rubin and Petrocelli (2015). Much of the study design employed by Rubin and Petrocelli was employed in the present study design. Specifically, participants were asked to observe several pre-recorded videos of a coin (black on one side and blue on the other side) being flipped. Unbeknownst to the participants, the series of coin flips
presented the coin as biased, such that the coin was more likely to land on the blue side (75% of the coin flips landed blue). Participants were randomly assigned to an observer condition or a predictor condition. Observer condition participants simply watched the pre-recorded videos and the predictor condition made predictions for each coin-flip before watching the pre-recorded videos. Participants then rated their detection of the coin’s bias through a series questions that probed such discovery. Self-report of counterfactual frequency was also measured to determine if counterfactual frequency was indeed a mediator for any difference in bias detection among the experimental conditions.

Although a non-significant between-group difference was found with respect to bias detection, an indirect mediation model was supported by the data. That is, an indirect effect of the experimental condition on bias detection was found only when controlling for the mediating variable of counterfactual frequency. As predicted, Rubin and Petrocelli (2015) found a significant effect of experimental condition on Counterfactual Generation such that the predictor condition reported generating a greater number of counterfactuals than the observer condition. Furthermore, counterfactual frequency was significantly and negatively associated with detecting bias in the coin. This was interpreted as support for the dysfunctional view of counterfactuals, their role in interfering with bias detection, and the more general connection between counterfactual thoughts and the repeated-trial experiential learning deficit. The present research serves in part as a replication of these findings, but further investigates the role of counterfactual thinking.

Present Study Overview

The purpose of present study is twofold. First, the study is designed to replicate the observed finding of interference of counterfactuals with experiential learning in a
repeated trials paradigm in which an association is meant to be learned by the participant (Rubin & Petrocelli, 2015).

Second, if counterfactual thoughts interfere with learning in such a paradigm, then any variable that interferes with the generation of counterfactuals should eliminate the deleterious effect of counterfactuals. Thus, it is proposed that high cognitive load could remove the negative effects that counterfactuals produce, thereby providing evidence for a potential mechanism. This reasoning is based on the notion that working memory is a component that underlies the generation of counterfactual thoughts, and thereby critical to creating memory traces that interfere with the detection of biased probabilities from repeated exposures. Working memory is a mental system that manipulates and stores information (Baddeley & Hitch, 1974). It has been well-studied and thoroughly documented, but it is useful here because there is a well-established methodology for interfering with its functioning in a flexible, frequently-used paradigm.

Cognitive load is the mental resource expended by working memory operations (Sweller, 1988). By manipulating external, experimentally-originating cognitive load, researchers are able to adjust the amount of resources available to participants for other working memory tasks.

As described earlier, counterfactual thoughts are believed to utilize a memory trace (and this memory trace is a potential explanation for the noted experiential learning deficit). Evidence (Tsai & McNally, 2014) indicates that cognitive load tasks can interfere with memory trace formation, implying that working memory may indeed play a vital role in the functioning of counterfactuals. If this is true, high cognitive load may be expected to greatly reduce counterfactual thought generation. If cognitive load indeed
interferes with counterfactual generation, eliminating the deleterious effect of counterfactuals on learning, this would prove to be an important step toward illuminating the role of counterfactual thoughts in the case of experiential learning inhibition.

Following from Rubin and Petrocelli (2015), participants in the present study were repeatedly exposed to videos of a coin being flipped. The association to be learned from the repeated trials is between the coin itself and its probability of a biased outcome – the coin did not show the standard 50/50 split expected of an unbiased coin. Past research on the illusion of control has used coin-flips to demonstrate other psychological phenomenon (Langer, 1975), but to date no reported research describes how interactions with biased coin-flips affects decision-making processes or are related to counterfactual thinking. Here, I define a biased coin as a coin that, when flipped, through some type of manipulation either internal or external to the coin itself, reliably lands on one side more than 50% of the time.

For the purposes of examining the role of counterfactual thinking, participants were randomly assigned to one of four conditions, created by crossing Task Role (observe vs. predict) with Cognitive Load (high vs. low): a) observers who simply observed a series of coin-flips under low cognitive load; b) predictors who observed a series of coin-flips but also made a prediction about the outcome of each flip, under low cognitive load; c) observers under high cognitive load, and d) predictors under high cognitive load. Each condition watched the same set of videos of the same coin being flipped 40 times, with one side coming up 75% of the time. Importantly, the participants were not directly informed that the coin was biased. The dependent variables involved the degree to which participants recall coin flip outcomes consistent with the perception that
the coin might be biased, their reports as to actual outcomes of the flipping events, and their predictions for future coin-flipping trials.

Counterfactuals are believed to be involved in the process by being differentially generated by the conditions. There are several reasons why the predictor condition might tend to generate significantly more counterfactuals than the observer condition. First, and most generally, predictors will conceivably be more invested in the outcomes of the activity, since they are active participants instead of passive. Research shows that, in a given context, the more involved an individual is in the situation, the more counterfactuals they tend to generate (Macrae & Milne, 1992; Meyers-Levy & Maheswaran, 1992).

The other central reason why I predict greater levels of counterfactual generation from the predictor conditions is the negative outcome of failed predictions. Research shows that undesirable outcomes are closely tied with greater counterfactual thought production. They are more readily available when outcomes are negative (Gavanski & Wells, 1989), and are more often produced by negative outcomes than neutral or positive outcomes (Markman et al., 1993). While it could be correctly pointed out that those who are in the predictor condition will also experience positive events (with the associated relative reduction of counterfactual production), it seems unlikely that those in the observer condition will experience significantly more positive or negative events. Considering that they are simply observing, it is not presumptive to claim that the large majority of their experiences will be neutral, which is also associated with lower levels of counterfactual thought generation.
With regard to the manipulation of cognitive load, the low cognitive load involved memorizing randomly generated two-letter strings, which were given before each trial and requested for input at the end of each trial. The high cognitive load was exposed to the same procedures, but used six-letter strings instead. Rehearsal is a core component of working memory (Baddeley & Hitch, 1974), and so memorization will optimally tax working memory by increasing cognitive load. The cognitive load manipulation should also have produced a main effect on counterfactual thought frequency, bias detection, and predictions of future coin flips favoring the blue outcome. However, each of the main effects is expected to be qualified by a Task Role × Cognitive Load interaction. Because counterfactual thought frequency is expected to be negatively associated with the detection of bias in the coin, counterfactual thought frequency is expected to mediate the Task Role × Cognitive Load interactive effect on both bias detection and predictions of future coin flips favoring blue.

**Hypotheses**

The current research was designed to test the following hypotheses:

**Hypothesis 1.** Hypotheses concerning the effect of Task Role:

**Hypothesis 1A.** A main effect of Task Role is expected to emerge for Counterfactual Generation, such that participants assigned to the predictor condition report a greater estimate of counterfactuals than participants assigned to the observer condition. This prediction is consistent with earlier research on the connections between counterfactual thinking, vested interest, and personally experienced, undesirable outcomes (Gavanski & Wells, 1989; Macrae & Milne, 1992; Markman et al., 1993; Meyers-Levy & Maheswaran, 1992).
**Hypothesis 1B.** A main effect of Task Role is expected to emerge for both Estimated Proportion of Biased Outcomes and Hypothetical Predictions Favoring Biased Outcomes, such that participants assigned to the observer condition report a greater proportion of biased outcomes and report a greater number of hypothetical predictions favoring biased outcomes than the participants assigned to the predictor condition. This prediction is consistent with earlier research on the connections between counterfactual thinking, vested interest, and personally experienced, undesirable outcomes, and with research indicating that greater levels of counterfactual generation lead to lower levels of bias detection (Rubin & Petrocelli, 2015).

**Hypothesis 1C.** Counterfactual Generation is expected to mediate the main effect of Task Role on both Estimated Proportion of Biased Outcomes and Hypothetical Predictions Favoring Biased Outcomes. This prediction is consistent with a mediation connection between Hypothesis 1A and Hypothesis 1B.

**Hypothesis 2.** Hypotheses concerning the effect of Cognitive Load:

**Hypothesis 2A.** A main effect of Cognitive Load is expected to emerge for Counterfactual Generation, such that participants assigned to the low cognitive load condition report a greater estimate of counterfactuals than participants assigned to the high cognitive load condition. This prediction is consistent with earlier research concerning rehearsal and working memory taxation by cognitive load (Baddeley & Hitch, 1974; Sweller, 1988).

**Hypothesis 2B.** A main effect of Cognitive Load is expected to emerge for both Estimated Proportion of Biased Outcomes and Hypothetical Predictions Favoring Biased Outcomes, such that participants assigned to the high cognitive load condition report a
greater proportion of biased outcomes and report a greater number of hypothetical predictions favoring biased outcomes than the participants assigned to the low cognitive load condition. This prediction is consistent with earlier research concerning rehearsal and working memory taxation by cognitive load, and with earlier research indicating that greater levels of counterfactual generation lead to lower levels of bias detection (Rubin & Petrocelli, 2015).

**Hypothesis 2C.** Counterfactual Generation is expected to mediate the main effect of Cognitive Load on both Estimated Proportion of Biased Outcomes and Hypothetical Predictions Favoring Biased Outcomes. This prediction is consistent with a mediation connection between Hypothesis 2A and Hypothesis 2B.

**Hypothesis 3.** Hypotheses concerning the interactive effect of Task Role × Cognitive Load:

**Hypothesis 3A.** A Task Role × Cognitive Load interaction is expected to qualify the expected main effects for Counterfactual Generation. A significant simple effect for the predictor condition is expected to emerge such that participants assigned to the low cognitive load condition report greater generation of counterfactual thoughts than participants assigned to the high cognitive load condition. However, no such effect is expected to emerge for the observer condition, such that high and low cognitive load condition participants report the same level of counterfactual thoughts. Furthermore, a significant simple effect is expected to emerge for the low cognitive load condition in which participants assigned to the predictor condition report a greater estimate of counterfactuals than participants assigned to the observer condition. Finally, no significant simple effect is expected to emerge for the high cognitive load condition, such
that participants assigned to the predictor and observer conditions report similar estimates of counterfactual generation. These predictions are consistent with the theory that counterfactual thoughts depend on working memory and rehearsal to be stored. Interfering with those processes via cognitive load would prevent participants from later reporting the generation of counterfactual thoughts.

**Hypothesis 3B.** A Task Role × Cognitive Load interaction is expected to qualify the expected main effects for both Estimated Proportion of Biased Outcomes and Hypothetical Predictions Favoring Biased Outcomes. A significant simple effect for the predictor condition is expected to emerge such that participants assigned to the high cognitive load condition report a greater proportion of biased outcomes and report a greater number of hypothetical predictions favoring biased outcomes than participants assigned to the low cognitive load condition. However, no such effect is expected to emerge for the observer condition, such that high and low cognitive load condition participants report the same level of the proportion of biased outcomes and number of hypothetical predictions favoring biased outcomes. Furthermore, a significant simple effect is expected to emerge for the low cognitive load condition such that there is a significant simple effect at low load in which participants assigned to the observer condition would report a greater proportion of biased outcomes and report a greater number of hypothetical predictions favoring biased outcomes than participants assigned to the predictor condition. Finally, no significant simple effect is expected to emerge for the high cognitive load condition, such that participants assigned to the predictor and observer conditions report similar proportions of biased outcomes and numbers of hypothetical predictions favoring biased outcomes. These predictions are consistent with
the theory that counterfactual thoughts depend on working memory and rehearsal to be stored. Interfering with those processes via cognitive load would prevent participants from later reporting having generated counterfactual thoughts. These predictions are also consistent with earlier research indicating that greater levels of counterfactual generation lead to lower levels of bias detection (Rubin & Petrocelli, 2015).

*Hypothesis 3C.* Counterfactual Generation is expected to mediate the Task Role × Cognitive Load interactive effect on both Estimated Proportion of Biased Outcomes and Hypothetical Predictions Favoring Biased Outcomes. This prediction is consistent with a mediation connection between Hypothesis 3A and Hypothesis 3B. That is, a mediated moderation model is expected to emerge from the data. Mediated moderation, as described by Muller, Judd, and Yzerbyt (2005; see also Wegener & Fabrigar, 2000), occurs when two independent variables (e.g., Task Role and Cognitive Load) interact to influence a proposed mediator variable (e.g., Counterfactual Generation), with that mediator directly carrying the effect of the interaction variables to the criterion (e.g., Estimated Proportion of Biased Outcomes and Hypothetical Predictions Favoring Biased Outcomes).
METHOD

Participants

A total of 230 participants (135 female) were recruited. The age of the participants ranged from 18 to 22, with a mean of 18.86. 77.3% of the sample was freshmen. Participants were Wake Forest University undergraduates, recruited through the online Wake Forest University psychology participation pool. Each participant signed an informed consent form to participate in a 60-minute research session and received partial course credit for their participation.

A total of 19 participants (10 female) were excluded from all subsequent data analyses. These participants were excluded for scoring +/- 2 standard deviations or more from the mean on the primary dependent variable, Estimated Proportion of Biased Outcomes. Scores in this range strongly suggest that these participants either failed to understand the question pertaining to the primary dependent variable or, for one reason or another, were indifferent to the 40 trial outcomes; many of the excluded participants reported an Estimated Proportion of Biased Outcomes of 0% or 100%. The number of participants excluded from the analyses were not dependent on Task Role or Cognitive Load, as evidenced by a non-significant 2 (Task Role: observer vs. predictor) × 2 (Cognitive Load: high vs. low) chi square, $\chi^2(1, N = 19) = .00, p = .96$. The final participant count for the subsequent analyses was 211.

Design

The study employed a 2 (Task Role: observer vs. predictor) × 2 (Cognitive Load: high vs. low) between-subjects experimental design in which participants were randomly assigned to one of four conditions. The research assistants administering the study were
blind to the condition for which each participant was assigned. Dependent variables and potential mediator variables included questions concerning bias detection and counterfactual thought responses.

**Procedure**

Upon arrival, each participant was greeted by a research assistant and led to a room in which he/she signed an informed consent form. From there, the participant was led to a private cubicle equipped with a personal computer with a welcome screen-frame of the study already displayed. Each participant was informed that he/she was to be asked to complete a coin-flipping task and to complete a self-administered questionnaire. Participants remained in their assigned cubicles for the duration of the study protocol. The study employed MediaLab v2012 (Jarvis, 2012) to present all study instructions and stimuli.

**Task role.** After the introduction screen-frames, participants were informed that they were about to watch pre-recorded videos of a blue/black coin being flipped (recorded prior and consisting of a blue and black poker chip glued together and being flipped on green felt). Participants randomly assigned to the *observer condition* were then instructed to pay attention to the coin-flips, as they would be asked about them later in the study; participants randomly assigned to the *predictor condition* were asked to make predictions concerning the outcome of the upcoming coin-flip by checking a box labeled BLUE or a box labeled BLACK on the screen-frame prior to each video being played (see Appendix A).

All participants viewed the same 40 coin-flip videos. The 40 trials were divided into five blocks of eight videos each, with associated prompts around the videos.
depending on the condition and one anagram task (consisting of a single anagram item) at the end of each block (see Anagram Task). The blocks were not delineated for the participants beyond the regular occurrence of the anagram tasks. The bias of the videos within each block was always represented by six videos of the coin landing on the blue side (“blue flips”) to two videos of the coin landing on the black side (“black flips”). The order of the videos within each block was randomized during questionnaire construction and all participants received the trial displays in the same order.

Before each video, the predictor condition participants were instructed to “Make your selections for the next trial. Select only one color. That is, select BLACK or BLUE.” After each video, all participants were asked: “What was the outcome of the last coin-flip that you observed?” Participants selected BLACK or BLUE, and then advanced to the next trial (or anagram).

**Anagram task.** All participants were informed that they would be periodically presented with an anagram task in which they were to unscramble five letters given to them to make a word. It was explained to participants that, in previous studies, researchers found an association between performance on the task and intelligence; this subterfuge was to help ensure attention and precision on the upcoming task.

After the first block of eight coin-flipping trials, participants in both conditions were shown instructions for an anagram task, examples for completed anagrams, and then given one to solve (see Appendix B). An example item gives the participants the string “TELSY” and asks them to unscramble it; the correct answer is “STYLE.” After typing in their completed anagrams, participants would move on to the next block of coin-flipping trials. After the first anagram item, subsequent anagrams were presented without
further explanation. The purpose of the anagrams was to avoid a situation in which participants simply counted the number of blue and black outcomes they saw by taxing them cognitively on regular intervals between coin flipping trials.

**Cognitive load manipulation.** Participants were instructed that they would be asked to remember strings of letters during each coin-flipping trial. While the number of letters presented differed depending on whether the participant was randomly assigned to a *low cognitive load* (two letters) or *high cognitive load* (six letters), the same instructions were given to both conditions.

Before each coin-flipping trial, participants in all conditions were presented with a string of letters and asked to remember them for entry after the trial. Strings were generated by using an online random letter generator, using a draw pool of the Roman alphabet with the vowels removed. These were generated randomly during questionnaire construction but remained consistent across participants. After each coin-flipping video, participants were asked to input the string they were to remember, with the appropriate number of blanks to match the number of letters given at the beginning of the trial.

**Dependent variables.** After the 40 coin-flip trials and five anagram tasks were completed, participants answered four sets of questions (see Appendix C). Questions 1-10 asked the participants to make ten predictions for ten more hypothetical coin-flips (each presented individually), in order to produce a set of responses that may lend insight into any implicitly detected bias.

Questions 11-15 concerned the anagram task and are not relevant to the conclusions of the proposed study.
Questions 16-18 directly addressed the degree to which participants detected the 75% percent bias of the coin that they observed. These items included: “How many flips total did you see?”, “With regard to the BLACK/BLUE coin, how many BLUEs did you see?”, and “With regard to the BLACK/BLUE coin, how many BLACKs did you see?”

Questions 19-23 concerned the potential mediator, counterfactual frequency, and attempted to determine how much counterfactual generation occurred for each participant. Items included: “Now we would like you to think back to the coin-flipping task. After you received feedback for coin-flipping trials, how often did you generate an “If only…” thought (i.e., think about alternatives to what actually occurred in the trial)?” and “When the BLACK/BLUE coin was flipped, how often did you think about alternatives to what actually happened in the trial?” using response scales with 1 (very infrequently) and 9 (very frequently) as the anchor labels.

**Demographics and debriefing.** Participants then completed a brief demographics questionnaire (gender, age, number of siblings, birth order, academic year in college, and whether or not they are a psychology major; see Appendix D). Finally, participants completed a “What Happens in the Lab Stays in the Lab” page, which first reminded participants about the confidentiality of what they’ve seen in an attempt to prevent any participant crosstalk (see Appendix E), and then asked them to agree to inhibit crosstalk. Participants were then provided with a debriefing statement that informed them as to the purpose of the study, the purpose of the anagrams, the purpose of the memorizations tasks, and the fact that the coins were biased (see Appendix F). Participants were then permitted to leave without further interaction with the research assistant, and were given credit for participation.
RESULTS

Variables and Descriptive Statistics

Of the 211 participants, 105 were in the observer condition and 106 were in the predictor condition, and 103 were in the low load condition and 108 were in the high load condition. The variable Attention ($M = .96, SD = .05$) was calculated by averaging the attention check scores on each trial, for which 1 represented that the participant correctly recorded the flip that had just occurred and 0 represented that the participants incorrectly recorded the flip. The Counterfactual Generation ($M = 4.20, SD = 1.59$) was calculated by averaging the scores on counterfactual questions, both of which were scored on a 1 (very infrequently) to 9 (very frequently) response scale. These two questions were selected due to their straightforwardness and clarity, as well as both asking how often counterfactual thoughts were generated, as opposed to how easy it might have seemed to generate counterfactuals.

The Estimated Proportion of Biased Outcomes variable ($M = .64, SD = .11$) was calculated by dividing the number of blue flips the participant reported viewing by the number of total flips the participant reported viewing. This variable served as the primary dependent variable in the study, representing bias detection. The Hypothetical Predictions Favoring Biased Outcomes variable ($M = .64, SD = .17$) was calculated by asking participants the expected outcome of ten future hypothetical coin flips, and then determining the proportion of those which were recorded as blue. While a perfect representation of the rates present in the current study would be 75% blue, the optimal strategy for guessing future coin flips would be maximizing (i.e., uniformly selecting blue for each trial). A participant that both perfectly detected the bias and perfectly
produced an optimal guessing strategy based on that bias would have selected “blue” for all ten hypothetical future coin flips. Therefore, the total out of 10 that a participant answered blue was considered a valid measure of bias detection combined with hypothetical guessing strategy formation. Estimated Proportion of Biased Outcomes was correlated with Hypothetical Predictions Favoring Biased Outcomes, $r(209) = .42$, $p < .001$.

**Attention**

Before addressing the tests of the key hypotheses (all of which relate to the possibility that bias detection may be inhibited by cognitive distortions), it was important to determine whether or not the study design had any effect on another source of cognitive distortion (i.e., attention to the actual outcomes of the coin-flipping trials). Thus, an Attention index was calculated by finding the proportion of correct responses to the 40-trial observed outcome probes.

A two-way analysis of variance (ANOVA) test was conducted to examine the potential effects of Task Role and Cognitive Load on Attention (see Figure 1). This analysis revealed a main effect of Cognitive Load on Attention, $F(1, 207) = 10.42$, $p < .01$, with the low cognitive load condition ($M = .97$, $SD = .03$) showing a significantly greater level of attention than the high cognitive load condition ($M = .95$, $SD = .05$). Although participants assigned to the predictor condition showed greater overall attention to the coin flipping outcomes ($M = .96$, $SD = .05$) than participants assigned to the observer condition ($M = .95$, $SD = .05$), this difference was not statistically significant, $F(1, 207) = 1.60$, $p = .21$, nor was the significant main effect qualified by a significant Task Role × Cognitive Load interaction, $F(1, 207) = .15$, $p = .70$. 
Counterfactual Generation was measured by asking participants to report how often they experienced mentally-simulated alternatives to reality during the experiment. To directly test Hypotheses 1A, 2A, and 3A, a 2 (Task Role) × 2 (Cognitive Load) ANOVA was conducted on the Counterfactual Generation data (see Figure 2). Consistent with Hypothesis 1A, this analysis revealed a significant main effect of Task Role, $F(1, 207) = 15.38, p < .01$, such that the observer condition ($M = 3.78$, $SD = 1.51$) reported a significantly lower generation of counterfactuals than the predictor condition ($M = 4.61$, $SD = 1.56$). A significant main effect of Cognitive Load was not observed, $F(1, 207) = 2.56, p = .11$, nor was the significant main effect qualified by a significant
Task Load × Cognitive Load interaction, $F(1, 207) = .257, p = .61$. Thus, no support was found for Hypotheses 2A and 3A.

Figure 2

Counterfactual Generation mean by Task Role and Cognitive Load

Note. Error bars are displayed at one SE above and below their respective condition means.

**Estimated Proportion of Biased Outcomes**

Estimated Proportion of Biased Outcomes was calculated by dividing the number of blue outcome flips participants reported observing by the number of total flips participants reported observing. To directly test the first bias detection variable of Hypotheses 1B, 2B, and 3B, a 2 (Task Role) × 2 (Cognitive Load) ANOVA was conducted on the Estimated Proportion of Biased Outcomes data (see Figure 3). Consistent with Hypothesis 1B, this analysis revealed a significant main effect of Task Role, $F(1, 207) = 4.72, p < .05$, such that the observer condition ($M = .66$, $SD = .11$) reported significantly greater bias detection than the predictor condition ($M = .63$, $SD = .15$).
A significant main effect of Cognitive Load was not observed, $F(1, 207) = .00$, $p = .97$, nor was the significant main effect qualified by a significant Task Role × Cognitive Load interaction, $F(1, 207) = .02, p = .89$. Thus, no support was found for the first bias detection variable of Hypotheses 2B and 3B.

Figure 3

Estimated Proportion of Biased Outcomes mean by Task Role and Cognitive Load

Note. Error bars are displayed at one SE above and below their respective condition means.

**Hypothetical Predictions Favoring Biased Outcomes**

Hypothetical Predictions Favoring Biased Outcomes was represented by the proportion of blue responses to the 10 hypothetical future coin flips. To directly test the second bias detection variable of Hypotheses 1B, 2B, and 3B, a 2 (Task Role) × 2 (Cognitive Load) ANOVA was conducted on the Hypothetical Predictions Favoring Biased Outcomes data (see Figure 4). Consistent with Hypothesis 1B, this analysis revealed a significant main effect of Task Role, $F(1, 207) = 4.57, p < .05$, such that the
observer condition ($M = .67, SD = .14$) reported significantly greater bias detection than the predictor condition ($M = .62, SD = .20$). A significant main effect of Cognitive Load was not observed, $F(1, 207) = 1.99, p = .16$, nor was the significant main effect qualified by a significant Task Role × Cognitive Load interaction, $F(1, 207) = .01, p = .91$. Thus, no support was found for the second bias detection variable of Hypotheses 2B and 3B.

Figure 4

Hypothetical Predictions Favoring Biased Outcomes mean by Task Role and Cognitive Load

Note. Error bars are displayed at one $SE$ above and below their respective condition means.

Mediation Analyses

Because Hypotheses 3A and 3B were not supported by the observed data, there was no reason to directly test the hypothesized mediated moderation model (i.e., Hypothesis 3C). However, it is reasonable to test the possibility that Counterfactual Generation mediates the main effects of Task Role on the dependent variables.
A mediation analysis was conducted using Task Role as the independent variable, Counterfactual Generation as the mediator, and the Estimated Proportion of Biased Outcomes as the criterion. As displayed in Figure 5, Task Role was a significant predictor of the Estimated Proportion of Biased Outcomes, $\beta = -.15, p < .05$, as well as Counterfactual Generation, $\beta = .26, p < .05$. When including Counterfactual Generation as an additional predictor of Estimated Proportion of Biased Outcomes, Counterfactual Generation was not a significant predictor of Estimated Proportion of Biased Outcomes, $\beta = .04, p = .58$, and the effect of Task Role was still significant, $\beta = -.16, p < .05$.

Figure 5

Mediation of the relationship between Task Role and Estimated Proportion of Biased Outcomes by Counterfactual Generation

A mediation analysis was conducted using Task Role as the independent variable, Counterfactual Generation as the mediator, and the Hypothetical Predictions Favoring Biased Outcomes as the criterion. As displayed in Figure 6, Task Role was a significant predictor of the Hypothetical Predictions Favoring Biased Outcomes, $\beta = -.15, p < .05$, as
well as Counterfactual Generation, $\beta = .26$, $p < .05$. When including Counterfactual Generation as an additional predictor of Hypothetical Predictions Favoring Biased Outcomes, Counterfactual Generation was not a significant predictor of Estimated Proportion of Biased Outcomes, $\beta = .09$, $p = .21$, and the effect of Task Role was still significant, $\beta = -.17$, $p < .05$.

Figure 6

Mediation of the relationship between Task Role and Hypothetical Predictions Favoring Biased Outcomes by Counterfactual Generation
DISCUSSION

The roles of predicting stimulus outcomes as opposed to simply observing stimulus outcomes, and counterfactual thinking, in an experimental learning deficit were directly investigated by the current research. Drawing from the existing literature, three different hypotheses were tested, with three sections for each. The observed experimental data supported two of these hypotheses. In accordance with Hypothesis 1A, participants who were assigned to the predictor conditions generated significantly more counterfactual thoughts than did the participants assigned to the observer conditions. In accordance with Hypothesis 1B, participants who were assigned to the predictor condition showed significantly worse bias detection compared to participants assigned to observer condition. Because cognitive load had no significant main effect on Counterfactual Generation (Hypothesis 2A) or either of the two bias detection variables (Hypothesis 2B), and there were no significant interactions (Hypotheses 1C and 2C), Hypothesis 3C was not tested, as mediated moderation requires for there to be moderation in the first place.

None of the mediation models concerning Task Role, Counterfactual Generation, or bias detection were supported. However, the significant main effects of Task Role on both Counterfactual Generation and bias detection provide preliminary evidence for the general proposal that more frequency counterfactual thought responses (as produced by predictions in an experiential learning scenario as opposed to simple observations) can lead to lower levels of bias detection. Further discussion will take this as a likely possibility, with the caveat that more evidence is warranted to firmly make such a claim.
The proposed effect of cognitive load was that participants who were under high levels of cognitive load would be less able to use their working memories for counterfactual generation, which would produce fewer counterfactual responses and greater bias detection. This was not found; there was no significant effect of Cognitive Load on Counterfactual Generation or Bias Detection. This null effect may be due to the fundamental nature of counterfactuals. That is, previous research has identified counterfactuals as automatic (Goldinger, Kleider, Azuma, & Beike, 2003; Roese, Sanna, & Galinsky, 2005). The spontaneous and effortless nature of counterfactual thoughts may prevent them from being affected by cognitive load manipulations. This does not mean that there is no methodology available that would enable a researcher to interfere with counterfactual generation while leaving the triggering event intact; these results simply indicate that cognitive load (and therefore working memory) may not be the mechanistic route for such an interference. Future research may do well by considering alternative methods of counterfactual response inhibition or more complex decision tasks that elicit counterfactual thinking without compromising the potential to detect bias.

However, given the assumption that greater levels of counterfactuals lead to worse bias detection, there are important previous findings to consider; an example is the research reported by Kao and Wasserman (1993). Their research participants gave causal strength attributions after repeated trials of stimulus observation; even when participants viewed stimuli that had perfect cause-effect relationships (so that every time a button was pressed a light would go on, and the light would not come on otherwise; or vice versa), they would fail to assess the relationships as perfectly causal. Counterfactual thoughts may serve as the mechanism underlying such a phenomenon. While the exact nature of
the cause-effect relationship being determined may differ between the Kao and Wasserman study and the current one, participants in both experimental paradigms had to ascertain the deterministic nature of an external, repeated-trial stimulus. In the present study, counterfactuals may have mediated that determination such that generating counterfactual thoughts occluded the true nature of the stimulus; perhaps it was counterfactual thinking that prevented a perfect causal judgment in the Kao and Wasserman study.

Other research that gains clarity when interpreted through the present study’s findings is the Newell and Rakow (2007) dice-rolling study. When participants rolled biased dice themselves, they were less likely to conform their predictions to the optimal strategy than if they had simply observed the dice being rolled. Because the current study has found that interacting with a stimulus produces a greater number of counterfactual thoughts concerning the stimulus than simply observing it, counterfactuals may have been the mechanism underlying their participants’ tendency to develop sub-optimal strategies when rolling the dice compared to simply observing the dice.

A point worth noting is that neither of the two studies cited above (Kao & Wasserman, 1993; Newell & Rakow, 2007) were framed or investigated in light of counterfactual thoughts. These failures of repeated-trial bias detection were instead discovered in the course of investigations of other phenomena. This indicates the potential for the generalizability of the present findings – they can apply to any situation involving repeated trials, whereby counterfactual thoughts are explicitly, or not explicitly, recorded. Thus, counterfactual thoughts may be a partial explanation for a wide variety of experiential learning deficiencies.
The present research can also serve to add to the debate concerning the functional and dysfunctional views of counterfactual thinking. There is ample previous support for both the functional (Epstude & Roese, 2008; Kray et al., 2009; Markman et al., 1993; Nasco & Marsh, 1999; Roese, 1997) and dysfunctional (Petrocelli & Harris, 2011; Petrocelli et al., 2013, 2012; Sherman & McConnell, 1995) view of counterfactual thoughts. Given that good decision making and learning are critical to the human condition, it appears that the present research may provide further support for the dysfunctional view of counterfactuals.

There may be several reasons for competing narratives concerning the effect that counterfactual thought generation has on future performance. In certain cases of support for the functional view (i.e., Nasco & Marsh, 1999), the research fails to differentiate between counterfactual thoughts and more simply, attention to the learning task. In fact, the Nasco and Marsh study asked participants to generate counterfactual thoughts concerning test-taking behavior following a test in a class, and the effect of the counterfactual thoughts was measured by determining participant performance on future tests. Participants who generated counterfactuals concerning the first test performed better on the second test. However, the participants in the counterfactual condition were contacted the day before the follow-up test to remind them of their counterfactual generation, confounding any potential report of the beneficial nature of counterfactuals with demand characteristics and simple cognitive salience.

Not all studies finding functional benefits from counterfactual thoughts suffer from design flaws, however. In general, there are several potential reasons why both functional and dysfunctional conclusions can pertain to counterfactual thoughts. In the
current study, counterfactual thoughts in the predictor conditions were almost certainly concrete and specific because participants received immediate visual feedback concerning their predictions (i.e., if the participant guessed black, and the coin landed blue, the potential counterfactual thought that would be generated would be highly potent because the participant would know factually what he/she could have or should have done). This lends the counterfactual thoughts a greater chance of distorting the memory of the actual event, and even supplanting it as the memory the participant feels is reality-accurate. Thus the concrete nature of the present study’s counterfactuals may have lent them a more dysfunctional nature compared to other studies’ less specific counterfactual thoughts.

Another potential reason that counterfactuals may sometimes be functional and sometimes dysfunctional concerns the content of the counterfactual thought itself. If a counterfactual thought has a strong actionable component and includes recognition criteria for when the situation that the counterfactual thought concerns arises again, it would be much more likely to have a functional result. However, if the counterfactual thought does not hold a specific action plan, does not contain a criterion for recognizing the scenario in the future, or is too general, it has a lesser chance of having a functional result. The counterfactuals most likely generated in this present study (i.e., “I should have picked blue.”), have no specific action plan and have no specific criterion for recognition; a participant does not know if there are future trials for which the counterfactual thought should apply more or less. However, other situations might have more actionable counterfactual thoughts along the lines of Epstude and Roese’s (2008) “content-specific pathway” (i.e., “When another test happens I should study more.”). Therefore, the content
of the counterfactual thought may determine whether it has a functional or dysfunctional effect.

The present research provides some initial support for the memory interference theory of dysfunctional counterfactual thoughts. This is supported by previous evidence that indicates that counterfactual thoughts have the potential to create interference in memory (e.g., De Brigard et al., 2013; Ferrante et al., 2013; Gerlach et al., 2014). Counterfactual thought generation has the potential to interfere with the accurate memories of an event, leading to worse recall after the fact and helping to create the noted failure of participants to learn biases after experiencing them in a trial-by-trial format (e.g., Kao & Wasserman, 1993).

**Similarities to Previous Studies**

There are several similarities between the design of this study and other previous dysfunctional counterfactual studies (e.g., Petrocelli et al., 2013). There are four important differences, however, that separate the present study from any prior research. First, the paradigm of the present study is relatively free of context features that were not ruled out as explanatory factors (e.g., spontaneous vs. directed counterfactual generation, distracting stimuli, clarity on what is to be learned) in previous studies. The present design involved four conditions interacting with the same stimuli, i.e. videos of a coin being flipped. The only assumptions that participants might bring into the experimental setting would concern coins, which is not a topic many people have rich associations with; this contrasts with a very complicated problem, like the Monty Hall problem (Petrocelli & Harris, 2011), or one which people have many associations and assumptions about prior to the study, like the stock market (Petrocelli et al., 2013).
The second important difference is that participants are never explicitly asked to generate counterfactuals anywhere in the paradigm. Instead, the observation and prediction conditions were expected to differentially generate counterfactuals spontaneously. Thus, the current design avoided such problems. The third important difference is that all previous studies have lacked the cognitive load component to test a potential mechanism of counterfactual thought learning interference.

Most importantly, the current study tested the observer versus predictor division as a proxy for differential counterfactual generation, which holds potential as a debiasing tool. Because predictors do indeed generate more counterfactuals and may perform more poorly on the bias detection measure, there is potential to generalize those conditions as a learning technique and thus have concrete, real-world benefits. When learning a complex system that contains biases, it may behoove individuals to at least initially witness the machinations of the system without creating predictions or guesses about how it operates.

Applied and Theoretical Implications

Gambling persistence is the rate at which participants continue to gamble over periods of time (Kassinove & Schare, 2001). Given gambling over time closely resembles trial-by-trial experiential learning, the present study almost certainly has implications concerning the persistence of gamblers. Gamblers who tend to counterfactualize may produce even more inaccurate estimates of their previous wins and losses. Because gambling losses, and wins associated with more desirable but forgone outcomes, tend to produce upward counterfactuals (i.e., “If I had performed this action differently I would have won more money.”), gamblers may have rosier pictures of their performance than reality warrants. Such a process may also contribute to an illusion of control (Langer,
1975). By manipulating the way that random betting events occurred, Langer’s (1975) participants believed they had a modicum of control over purely random events, which led to overconfidence when betting and gambling persistence. These control beliefs might be motivated by counterfactual thoughts – leading participants to imagine a hypothetical scenario where they possess control over a situation, and/or leading to the belief that they actually have control. It seems quite possible that some forms of gambling persistence are caused by a memory distortion originating from counterfactual thoughts. This possibility warrants future research.

Financial investing is another field in which repeated exposures to probabilistic representations form mental aggregates that one might hope to learn. Kahneman (2011) noted that there is an “illusion of skill” among investment bankers in which they believe that their performance is due to their own skill, even when confronted with hard evidence that their performance was merely due to luck or chance. Counterfactual thought generation could be the mechanism underlying such delusions; incorrect mental aggregates, caused by the memory distortion effect demonstrated in the present study, can be produced by counterfactual thoughts. Incorrect aggregates of performance would seem to influence investor decisions (as would correct aggregates) and beliefs in their own skills.

The phenomenon known as the sunk cost fallacy involves counterproductively investing further resources into a sub-optimal course of action due to one’s previous investments in that course of action (Staw, 1976). The present research may shed new light into the origin of this fallacy. Individuals, when investing initial resources into a specific course of action, may generate counterfactual thoughts upon learning that their
initial investment failed to return the results they expected. As the individuals renew their investment in the course of action, they may begin to encode a distorted memory, influenced by their counterfactual thoughts that justify continued supportive action.

**Limitations and Future Directions**

One of the primary reasons why the present study was unable to support significant mediation models may have been due to the presence of moderate to high cognitive load. Cognitive load directly affects memory, and the proposed effect of counterfactual thoughts is memory-based. Even the low cognitive load condition experienced more than zero load during the study, as these participants were asked to remember two letters across the trial. The noise and error produced by this second independent variable may have overwhelmed any mediation effect of the counterfactual thoughts themselves.

Another limitation of the current study is that Cognitive Load had no significant effect on any mediating or dependent variables. That is, the only effect that Cognitive Load had was that it reduced attention accuracy uniformly. However, this limitation of the current study also indicates a fruitful future direction: identifying an experimentally mutable mechanism that underlies counterfactual generation.

It can be concluded that Cognitive Load ended up resembling a cudgel, both failing to successfully affect the generation of counterfactuals and potentially muddling any mediation effects of the counterfactuals on bias detection. Future research could make headway by identifying a manipulation more akin to a scalpel; this would enable the research to selectively inhibit the generation of counterfactual thoughts, not interfere with a mediation effect of counterfactuals on bias detection, and make further steps
toward completely describing the effects that these mentally simulated alternatives to reality have on our everyday thought processes.
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Appendix A

Instructions

ALL PARTICIPANTS

Welcome to the OBSERVATIONS OR PREDICTIONS Study.

INSTRUCTIONS:

Please read all of the information carefully, otherwise you won't know what to do during the study.

Click Continue to begin.

PREDICTION CONDITION

Screen Frame 1

INSTRUCTIONS: This study deals with decision making under a variety of situations.

For the purposes of making decisions, we will show you PRE-RECORDED VIDEOS of the outcomes of a coin being flipped in each of several consecutive trials (a BLACK/BLUE coin).

We will ask you to make predictions for the outcomes of each coin-flip. We ask that you do the best you can, but not to take too much time in making your decisions.

You may continue by clicking the Continue button when it appears below.

Screen Frame 2

DECISION TRIALS: In a few moments, we would like you to make predictions for a series of consecutive coin-flips using the BLACK/BLUE coin. You will be asked to check a response button and to click the Continue button to signal that you are ready to proceed. The coin videos will then be played for you.

Please pay attention to the coin-flips, as we will ask you questions about the coin-flips later in the study.

You may continue by clicking the Continue button when it appears below.
Screen Frame 3

To vary difficulty, you may or may not be asked to complete an anagram task at varying intervals. You will also be asked to remember a set of letters at the beginning of each trial, and then asked to input those letters at the end of each trial.

PLEASE KNOW that in our previous research using these tasks, we have found performance to be positively and significantly correlated with various intelligence measures.

You may continue by clicking the Continue button when it appears below.

OBSERVATION CONDITION

INSTRUCTIONS: This study deals with observing outcomes under varying levels of cognitive load.

For the purposes of providing you with outcomes to observe, we will show you PRE-RECORDED VIDEOS of the outcomes of a coin being flipped in each of several consecutive trials (a BLACK/BLUE coin).

Please pay attention to the coin-flips, as we will ask you questions about the coin-flips later in the study.

You may continue by clicking the Continue button when it appears below.

Screen Frame 4

TRIAL PROGRESSION (40 Trials):

ALL PARTICIPANTS:

In the next screen frame we will display for you some letters. You will have ten seconds to remember the letters. After this time we will present you with the coin-flipping stage of the trial and then ask you to recall the letters. Please click Continue now.

Screen Frame 5

LOW COGNITIVE LOAD:

Here are the letters to remember for this trial:

GX
**HIGH COGNITIVE LOAD:**

Here are the letters to remember for this trial:

GXQBRH

**Screen Frame 6**

**PREDICTION CONDITION:**

Make your selections for the first trial. Select only one color. That is, select BLACK or BLUE.

[Buttons labeled “BLACK” and “BLUE” provided.]

**Screen Frame 7**

View video of coin-flip

**Screen Frame 8**

For the previous trial your prediction was ____ [correct/incorrect]

**Screen Frame 9**

**OBSERVATION CONDITION:**

Click the Continue button to view the first trial.

View video of coin-flip

**Screen Frame 10**

**ALL PARTICIPANTS:**

What was the outcome of the last coin-flip that you observed?

[Buttons labeled “BLACK” and “BLUE” provided.]

**Screen Frame 11**

Please do you best to fill in the blanks below with the letters you were asked to remember for this trial:

[fill-in-the-blank spaces provided]
Appendix B

Anagram Instructions, Examples, and Task Items

Anagrams are scrambled word problems and are a particularly important index of intellectual ability and aptitude. Solving an anagram involves unscrambling the letters to form an actual word. For example, "YHAPP" is an anagram, and its solution is "HAPPY". All of the anagrams you will see have only one correct solution.

Here are some additional examples of the types of anagrams you could see in the task that follows.

TEL Sy OWAMN GBRUY COFRE

Here are the solutions to the examples.

TEL Sy OWAMN GBRUY COFRE
STYLE WOMAN RUGBY FORCE

Task Items:

<table>
<thead>
<tr>
<th>ANAGRAM</th>
<th>SOLUTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>NBIAC</td>
<td>CABIN</td>
</tr>
<tr>
<td>KASNC</td>
<td>SNACK</td>
</tr>
<tr>
<td>PHTED</td>
<td>DEPTH</td>
</tr>
<tr>
<td>FTEIH</td>
<td>THEIF</td>
</tr>
<tr>
<td>EMCYR</td>
<td>MERCY</td>
</tr>
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<td>ORDCW</td>
<td>CROWD</td>
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<td>TRUCK</td>
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<td>KNIFE</td>
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<tr>
<td>IOLGC</td>
<td>LOGIC</td>
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<td>LKCOA</td>
<td>CLOAK</td>
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<td>COUNT</td>
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<td>IMENC</td>
<td>MINCE</td>
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<td>FIYRA</td>
<td>FAIRY</td>
</tr>
<tr>
<td>IPTLU</td>
<td>TULIP</td>
</tr>
</tbody>
</table>
Appendix C

Dependent Variables

Now we would like to ask you some questions about the tasks you completed.

Please click the Continue button at this time.

1) Imagine that the BLACK/BLUE coin was flipped in another ten trials. What is your prediction of the first trial? 
   [1 = BLACK; 2 = BLUE]

2) What is your prediction of the second trial? 
   [1 = BLACK; 2 = BLUE]

3) What is your prediction of the third trial? 
   [1 = BLACK; 2 = BLUE]

4) What is your prediction of the fourth trial? 
   [1 = BLACK; 2 = BLUE]

5) What is your prediction of the fifth trial? 
   [1 = BLACK; 2 = BLUE]

6) What is your prediction of the sixth trial? 
   [1 = BLACK; 2 = BLUE]

7) What is your prediction of the seventh trial? 
   [1 = BLACK; 2 = BLUE]

8) What is your prediction of the eighth trial? 
   [1 = BLACK; 2 = BLUE]

9) What is your prediction of the ninth trial? 
   [1 = BLACK; 2 = BLUE]

10) What is your prediction of the tenth trial? 
    [1 = BLACK; 2 = BLUE]

11) Did you complete all of the anagrams? 
    [1 = Yes; 2 = No]

12) What was the number of anagrams you completed? 
    [open-ended format]

13) How many total anagrams did you see in the anagram task? 
    [open-ended format]
14) What percentage of the anagrams do you think you answered correctly? [open-ended format]

15) How difficult did you find the anagram items to be? [0 = not at all difficult; 10 = extremely difficult]

16) With regard to the BLACK/BLUE coin, how many total flips did you see?

17) With regard to the BLACK/BLUE coin, how many BLACKs did you see? Please type a number in the box below using this format: xx [restricted to 0-100]

18) With regard to the BLACK/BLUE coin, how many BLUEs did you see? Please type a number in the box below using this format: xx [restricted to 0-100]

19) Now we would like you to think back to the coin flipping task. After you received feedback for coin flipping trials, how often did you generate an "If only…" thought (i.e., think about alternatives to what actually occurred in the trial)? [1 = very INFREQUENTLY; 9 = very FREQUENTLY]

20) After you received feedback for coin flipping trials, on average how easy or difficult would it have been for you to think about alternatives to what actually occurred in the trials? [1 = very DIFFICULT; 9 = very EASY]

21) After you received feedback for coin flipping trials, on average how easy or difficult was it for you to generate "If only…" thoughts (i.e., think about alternatives to what actually occurred in the trials)? [1 = very DIFFICULT; 9 = very EASY]

22) When the BLACK/BLUE coin was flipped, how often did you think about alternatives to what actually happened in the trial? [1 = very INFREQUENTLY; 9 = very FREQUENTLY]

23) When the BLACK/BLUE coin was flipped, how easy/difficult was it to think about alternatives to what actually happened in the trial? [1 = very INFREQUENTLY; 9 = very FREQUENTLY]
Appendix D

Demographics

1. Please indicate your gender.
   1 = Male, 2 = Female

2. Please indicate your age range.
   1 = 18, 2 = 19, 3 = 20 4 = 21, 5 = 22, 6 = 23, 7 = 24, 8 = 25, 9 = 26-29, 10 = 30-39,
   11 = 40-49, 12 = 50-50+

3. Including you and your siblings, how many children have been born into your immediate family?

4. Please indicate the placement of your birth in your family.
   1st, 2nd, 3rd, 4th, 5th, 6th, 7th, 8th, 9th, 10th, 11th, 12th

5. Please indicate your year in college.
   1 = Freshman, 2 = Sophomore, 3 = Junior, 4 = Senior, 5 = N/A

6. Are you a psychology major?
   1 = No, 2 = Yes, 3 = I am a psychology minor
Appendix E

Participant Crosstalk Prevention Message

You have completed the tasks involved in this study.

Please read the following statement:

We genuinely hope that you are learning something about psychology from your research experiences. However, researchers take a big risk by describing their research. The results of their research often depend on people showing up with no knowledge of the study. If people who go through a procedure tell others about it, this desirable lack of knowledge might no longer be there. Hence, there is a rule that we hope you will follow: WHATEVER HAPPENS IN THE LABORATORY STAYS IN THE LABORATORY.

This rule is really meant to discourage you from describing procedures to other students who could potentially participate in the study. Any student who participates in a study should do so without detailed foreknowledge of the procedures. Hence, please do not describe such details to people who might later participate. In this lab we conduct research, and at the same time, try our best to make the studies educational for you. To achieve both of these goals, we need you to not divulge details about this study to other people who could potentially participate in it. Thus, please follow this rule with respect to other PSY 151 students: WHATEVER HAPPENS IN THE LABORATORY STAYS IN THE LABORATORY.

Consistent with the WHATEVER HAPPENS IN THE LABORATORY STAYS IN THE LABORATORY rule, we would like to ask that you not tell any other PSY 151 students about this study. Is that okay with you?

[ ] Yes. I will adhere to the rule and not tell other PSY 151 students about this study.
[ ] No. I will not adhere to the rule.

Please note that there are no consequences, whatsoever, for responding “No” to this question.
Appendix F

Debriefing Statement

Observations or Predictions

DEBRIEFING STATEMENT: OBSERVATIONS OR PREDICTIONS

Thank you for your participation today. Your assistance is very much appreciated and extremely helpful to us in conducting our research. Before you go, we would like to tell you a little bit about our experiment.

This is an experiment in social psychology. Previous research has found when people assess the probabilities of random events the involvement of the participant in the event causes them to be more confident about their predictions. Further research has shown that people often emphasize successes, and downplay failures, creating a perception of success that does not exist. We are investigating whether this holds true when the event is not random (i.e., one outcome is more likely to occur than the other). We want to see how sensitive people are about detecting these biases in events, and whether or not the act of predicting events affects perceptions of those events. This is why we either asked you to make predictions and observe coin-flips or to just observe coin-flips.

When we presented you with the series of coin-flips, we intentionally biased the coin-flip outcomes. That is, the coin-flips were not random and this study involved deception. In fact, we deceived you in three additional ways. First, the purpose of the coin-flip predictions and/or observations at the beginning of the study was to determine whether or not predicting versus simply observing coin-flips makes a difference in one's memory for the actual outcomes and detection of biased stimuli. Second, the actual purpose of the anagram tasks was to make remembering the coin outcomes a bit more difficult. Finally, we led you to believe that performance on our tasks is correlated with various measures of intelligence. To our knowledge there is no such study suggesting this relationship. We led you to believe there was a correlation in hopes of motivating your to perform at your fullest potential.

If you have any questions about the study you can reach the principal investigator using the contact information listed on your copy of the informed consent form.

Thanks again for your help! As a final note, please do not discuss this experiment with anyone who might enroll in this study.

If you have any questions about any aspect of the reseach, or would like to learn more, contact Dr. John Petrocelli (petrocjv@wfu.edu).
ASHER L. RUBIN
rubial13@wfu.edu

EDUCATION
Wake Forest University, Winston-Salem, NC
M.A. in Psychology 2013 – Present
The College of William and Mary, Williamsburg, VA
B.S. in Psychology, Minor in Philosophy 2009 – 2013
Thomas Jefferson High School for Science and Technology, Alexandria, VA
Ranked #1 high school in country by U.S. News and World Report during attendance

RESEARCH EXPERIENCE
Petrolab, Wake Forest University
Dr. John Petrocelli 2013 – Present
Designed, wrote, and presented own project, administered studies
PPP Project, Wake Forest University
Dr. Will Fleeson, Dr. Michael Furr 2013 – 2014
Managed participants
Jayawickreme Lab, Wake Forest University
Dr. Eranda Jayawickreme 2014
Concept development, data entry
Cognitive Psychophysiology Laboratory, College of William and Mary
Dr. Paul Kieffaber 2012 – 2013
Designed and presented own project, administered studies

PROFESSIONAL PRESENTATIONS

TEACHING EXPERIENCE
Wake Forest University
Teaching Assistant – Various Courses 2013 – 2015
Taught courses, assisted professors with designing lecture
and course material, graded assignments, tutored students

AWARDS
Teaching Assistantship, for MA at Wake Forest 2013 – 2015
Charles Center Graduate Research Grant, for senior year
project at the College of William and Mary 2012 – 2013

MEMBERSHIPS
Society for Personality and Social Psychology
Association for Psychological Science

COMPUTER PROGRAM PROFICENCIES
MediaLab
Inquisit
Qualtrics