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DECEPTION AS COGNITIVE LOAD:

WORKING MEMORY, BLINK RATE, AND PUPIL DILATION

By

Reinalyn Echon

A thesis

submitted in partial fulfillment

of the requirements for the degree of

Master of Science in the Department of Psychology

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Abstract

Meta-analysis of deception research has shown that many common deception cues do not accurately discriminate between truths and lies (DePaulo et al., 2003). The present study sought to understand why the cognitive load approach to deception detection appears to more accurately discriminate between truths and lies than other approaches. Participants told the truth and lied about controversial topics while pupil size and blink rate were measured via eye tracker. Since lying is more cognitively demanding than truth telling (e.g., Vrij, Fisher, Mann, & Leal, 2008) and pupil dilation and blink rate are indicators of cognitive load (e.g., Dionisio, Granholm, Hillix, & Perrine, 2001; Holland & Tarlow, 1972), it was predicted that lie statements would show increased pupil dilation and decreased blink rate compared to truth statements. Higher working memory capacity was expected to mitigate the cognitive load of lying (Vrij, Fisher, et al., 2008). Main effects appeared to support hypotheses, but further investigation showed that these effects were primarily driven by differences to baseline. Furthermore, working memory differences appeared to be in opposite directions than hypothesized. Implications and future directions are discussed.

Keywords: deception, working memory, eye tracker, cognitive load, pupil, blink rate

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CHAPTER ONE

Deception as Cognitive Load: Working Memory, Blink Rate, and Pupil Dilation

Meta-analyses of almost 50 years of deception literature have shown that both laypeople and experts have a 54% accuracy rate, on average, of discriminating between truths and lies (Bond & DePaulo, 2006). According to meta-analyses of deception detection accuracy, the behavioral cues that both laypeople and experts use to determine whether someone is lying or telling the truth tend to be inaccurate indicators of deception (Bond & DePaulo, 2006; DePaulo et al., 2003). For example, foot or leg fidgeting was shown to be a very weak predictor, yielding a non-significant effect size (d = -0.09; DePaulo et al., 2003), despite the fact that people tend to state foot or leg fidgeting as one cue they believe indicates deception (The Global Deception Research Team, 2006). Bond and DePaulo (2006) also show that, even when behavioral cues are indicative of deception, the effect sizes are usually very small. For example, being nervous and tense while speaking significantly differentiated between truths and lies, but the observed effect size was still small (d = 0.27).

Even when different groups of researchers study the same deception cue, they often contradict each other. For example, Mann and colleagues (2012) found that liars made significantly more eye contact than truth tellers, but Walczyk, Griffith, Yates, Visconte, and Simoneaux (2013) found that liars made more eye movements in an effort to avoid making eye contact while speaking. One way to resolve these contradictory findings is to look at potential mechanisms that determine the presence of behavioral differences between liars and truth tellers. A frequently proposed, but rarely investigated, potential mechanism of deception is working memory (e.g., Sporer & Schwandt, 2006, 2007). Thus, the current study seeks to elucidate the role of working memory in deception by associating working memory span with cognitive effort – measured via eye tracking – expended during deception relative to truth telling.

Several theories of deception have been established (DePaulo et al., 2003; Walczyk, Igou, Dixon, & Tcholakian, 2013); the most influential theories will be outlined, starting with the Four-Factor Theory proposed by Zuckerman, DePaulo, and Rosenthal (1981). The Four-Factor Theory posits that the act of deception is too complex to be distilled to a single behavior or a single set of behaviors to differentiate between truths and lies. Instead, the Four-Factor Theory's strength is the understanding that truth tellers and liars experience different internal states which lead to different behavioral cues.

The four factors Zuckerman and colleagues (1981) identified as predictive of deception were: generalized arousal, emotions accompanying deception, cognitive aspects of deception, and attempted control of verbal and nonverbal behaviors. In terms of arousal, the Four-Factor theory states that liars experience more general arousal than truth tellers and that this arousal is indicated by cues such as higher vocal pitch, increased pupil dilation, and increased blink rate. In terms of specific emotions that accompany deception, Zuckerman and colleagues (1981) state that liars experience different emotions than truth tellers (e.g., guilt and fear). Behaviors associated with guilt and fear during deception include increased fidgeting and increased gaze aversion relative to truth telling. As for the cognitive aspects of deception, the Four-Factor Theory postulates that lying is a more cognitively complex task than truth telling and that behavioral cues indicative of the cognitive complexity of deception include longer response latencies, increased pauses in speech patterns, and fewer hand gestures relative to truth telling. Lastly, Zuckerman and colleagues (1981) state that liars attempt to control their verbal and nonverbal behaviors in a way that may appear unnatural or inconsistent, such as appearing less spontaneous and forthcoming than a truth teller would appear.

Another early model of deception that has informed deception literature is the Interpersonal Deception Theory proposed by Buller and Burgoon (1996). The primary focus of Buller and Burgoon's (1996) theory is that the liar engages in several simultaneous tasks to appear truthful to the message receiver. Among the many tasks that the liar must engage in while deceiving another person is to monitor and respond to the behavior of the message receiver, which is presumed to deplete cognitive resources. When the liar has to perform too many simultaneous tasks (e.g., monitor and respond to cues from the receiver, present a plausible lie, and so forth), the tasks create a "cognitive overload," which results in unintentional leakage. These signs of cognitive overload are similar to the cues proposed by Zuckerman and colleagues (1981) and include uncertainty and vagueness in a liar's account, frequent pauses, and dissociating from acts of deception (e.g., saying that it was a group decision instead of a personal choice).

Cognition of Deception

While several models exist to explain the underlying mechanisms of interpersonal deception ability, recent literature favors models based upon a cognitive framework. Cognitive models of deception detection are considered more effective because they recognize that deception is a cognitively demanding task (Gombos, 2006; Vrij, Fisher, Mann, & Leal, 2006; Zuckerman et al., 1981). The overall consensus of several cognitive models of deception (Buller & Burgoon, 1996; Sporer & Schwandt, 2006; Walczyk, Harris, Duck, & Mulay, 2014; Walczyk, Roper, Seemann, & Humphrey, 2003) is that successful liars must first inhibit the automatic impulse to tell the truth. When a question is asked, the truth is automatically activated in the mind; to lie, one must suppress this automatic response (Debey, De Houwer, & Verschuere, 2014). Reaction time studies have corroborated this truth suppression hypothesis; responding truthfully results in faster reaction times than responding deceitfully (Debey et al., 2014; Walczyk, Griffith, Yates, Visconte, & Simoneaux, 2013; Walczyk et al., 2014, 2003).

Second, after deciding to lie, one must create and then choose the most plausible lie out of the many generated to replace the truth (Walczyk et al., 2014, 2003). For instance, if lying about where one was when a crime was committed, one could state the location as a bar, home, hospital, or any other place as imagination allows that was not the scene of the crime. This decision takes more time to generate than telling the truth (as noted above) because, in an attempt to avoid suspicion, one needs to choose a plausible location that is not the crime scene nor a location that is wildly unlikely (e.g., Pluto), whereas telling the truth requires simply stating the location.

Third, one must then tell the lie in such a way as to avoid arousing suspicion of deception (Walczyk et al., 2014). For example, knowing that most people associate lack of eye contact with deception (The Global Deception Research Team, 2006), one may initiate eye contact to appear truthful (Buller & Burgoon, 1996). Fourth, one must assess the other person’s (i.e., the receiver/the deceived) behavior to assess whether the deception was successful (Buller & Burgoon, 1996; Walczyk et al., 2014). Thus, while lying, one would check for any sign that the receiver is suspicious of one’s account (e.g., repetitive questioning, frowning, asking for proof, commenting on suspicious behavior).

Considering the aforementioned amount of cognitive ballet required to successfully deceive, several researchers (e.g., Sporer & Schwandt, 2006) have posited that working memory, the ability to store and process relevant information to accomplish the task at hand (Baddeley & Hitch, 1974), is a central mechanism for deception.

Working Memory

Working memory capacity has been shown to be highly predictive of higher order cognitive functions such as reading/language comprehension, problem solving, and so on (Baddeley, 1992; Daneman & Carpenter, 1980; Daneman, Merikle, & Merikle, 1996; Engle, 2002). Working memory capacity is described as the amount of information one can both process and maintain in an active state.

A commonly used task to measure working memory capacity is the operation span (OSPAN). The operation span consists of solving elementary math equations (i.e., the processing component) while simultaneously remembering lists of words to be recalled later (i.e., the maintenance component; Turner & Engle, 1989). The scores for one's ability to correctly answer the math equations and recall words during the task allow researchers to create groups of high and low working memory spans. High working memory spans are individuals who can process and maintain information efficiently; these are the participants who score highly on the operation span task. Low working memory spans are those that have difficulty with simultaneously processing and maintaining information such that they score lower on the operation span task.

According to Sporer and Schwandt (2006, 2007), a working memory model of deception is a more promising approach for nonverbal and paraverbal cues of complex lies in applied settings. The working memory model is Sporer and Schwandt's adaptation of the cognitive load approach (Vrij et al., 2006), which posits that imposing a second, cognitively demanding task in addition to the already cognitively demanding task of lying will decrease the limited amount of cognitive resources available for successful lying thereby making the typically miniscule behavioral differences between truth tellers and liars more obvious to professional and amateur lie-catchers. This cognitive approach to deception detection has initiated investigations of several dual tasks or questioning techniques, including but not limited to: asking unanticipated questions (Lancaster, Vrij, Hope, & Waller, 2013), asking questions in the reverse order (Vrij, Mann, et al., 2008; Vrij, Leal, Mann, & Fisher, 2012), asking participants to answer from an opposite perspective from their own (i.e., the Devil's advocate approach; Leal, Vrij, Mann, & Fisher, 2010), and instructing participants to maintain eye contact for the duration of the interrogation (Vrij, Mann, Leal, & Fisher, 2010). All of the aforementioned dual tasks and interview techniques resulted in improved (i.e., significantly better than chance) deception detection accuracy. However, for their meta-analyses, Sporer and Schwandt (2006, 2007) believed that the cognitive load model was too general of an explanation since the term "cognitive resources" encompasses anything from response inhibition to working memory or any other executive function. Thus, the authors described working memory as a more parsimonious model of deception.

Working memory is a commonly hypothesized mechanism for deception ability since the simultaneous abilities to inhibit the prepotent truth response, choose a plausible lie, decipher interpersonal cues indicating that deception has not been detected, and change one's own behavior to appear truthful require the ability to maintain and process relevant information (i.e., working memory). Thus, differences in working memory capacity could help explain why some liars can be easily detected while others cannot. To further illustrate that working memory is a potential mechanism for deception, neuroscience studies of deception implicate several cognitive processes related to working memory.

Cognitive Neuroscience of Deception

Neuroimaging studies of deception have consistently implicated the anterior cingulate cortex (ACC) and the dorsolateral prefrontal cortex (DLPFC) as active during deceptive responses but not in truthful responses (for a review, see Abe, 2011; Ganis & Keenan, 2009; Spence et al., 2004). The anterior cingulate cortex (ACC), a brain region believed to be involved in resolving response conflicts and inhibition (Botvinick, Cohen, & Carter, 2004; Carter et al., 1998), has been implicated in deceptive responses in various studies. For instance, Johnson, Barnhardt, and Zhu (2004) conducted an event-related potential (ERP) study of deceptive and truthful responding. The results revealed that the medial frontal negativities (MFN), which are ERP signals associated with the ACC, during deceptive responses were significantly larger, suggesting that truthful and deceptive responses elicit different ACC activation. These ERP results imply that resolving response conflicts between the prepotent truth response and a deceptive response is a cognitive mechanism characteristic of deception. These results also elucidate that telling a lie results in longer latency times than telling a truth (Walczyk, Griffith, et al., 2013) through the process of resolving response conflicts between the prepotent truth response and the deceptive response.

Activation of the ACC has also been found using fMRI methodology. Langleben and colleagues (2002) instructed participants to select an envelope and memorize the value and suit of the playing card found within the envelope (in actuality, every envelope contained a five of clubs playing card). Then, when participants were in the MRI scanner, they were shown a card and asked if that was the playing card found in the envelope. Participants were instructed to only lie when the card they were shown was displayed on the screen. The results revealed that the right ACC showed increased activation during deceptive responding when compared to truthful responding. Since the ACC has been found to be associated with conflict monitoring (Carter et al., 1998), the authors concluded that increased activation of the ACC during deception was indicative of the process of resolving the response conflict between the deceptive response and the prepotent truth response. Additionally, Langleben and colleagues (2002) found that while certain brain regions were more active during deception, there were no brain regions that were more active during truth telling. Thus, truth telling is implied to be the baseline state of functioning which supports the findings of reaction time studies showing that truth telling has shorter latencies than deception (Debey et al., 2014; Walczyk et al., 2003).

The prefrontal cortex (PFC), another brain region believed to be involved in executive processes, is also commonly implicated in deceptive responses (Abe, 2011; Ganis & Keenan, 2009). In a positron emission tomography (PET) study (Abe et al., 2006), participants were asked to tell the truth or lie about having participated in a task (e.g., consulting a dictionary, coloring a picture, etc.). Imaging results revealed greater activation of the left dorsolateral prefrontal cortex (DLPFC; a more specific region of the PFC) during deception compared to truth telling. Prior cognitive neuroscience studies have associated activation of the left DLPFC with executive functioning (Spence et al., 2004). As such, Abe and colleagues (2006) concluded that the activation of the left

DLPFC indicates that executive functioning is a necessary cognitive process in the ability to deceive. Moreover, they hypothesized that the specific cognitive process implicated in their research could be working memory given a prior study noting that damage to the DLPFC correlated with deficits in working memory performance (Fujii, Fukatsu, Yamadori, Suzuki, & Odashima, 1997).

In a case study of a patient with bilateral frontal lobe infarcts, Fujii, Fukatsu, Yamadori, Suzuki, and Odashima (1997) describe how patient TM was suddenly afflicted with an inability to speak and write coherently. Magnetic resonance imaging (MRI) revealed brain lesions in the posterior half of the middle frontal gyrus, pars opercularis, and part of the pars triangularis on the right hemisphere as well as lesions on part of the pars opercularis and pars trianglaris on the left hemisphere. These areas correspond with the DLPFC and the superior portion of the ventrolateral prefrontal cortex. After several neuropsychological tests as well as tests of auditory and motor functioning to determine the exact dysfunction, the researchers concluded that TM's impairment was specific to transferring information from one mode of input to a different modality as output (e.g., hearing a series of number then pushing the buttons with the corresponding numbers). In comparison, TM had no difficulty when both the input and output were of the same mode (e.g., verbally repeating numbers verbally presented). Additionally, the patient had no difficulty with performing tasks with only a single item (e.g., pressing a single button) but did have difficulty when the tasks increased to remembering more items (e.g., pressing a series of buttons from memory), suggesting that his impairment was not due to a lack of comprehension or motor ability but due to the size of the tasks. The nature of TM's impairment implies that the patient has a deficit in working memory since his memory deficits only appeared when the number of items to remember increased and TM's specific impairment was in performing tasks that required changing modalities. Thus, this loss-of-function case study demonstrated the DLPFC as an area of the brain associated with working memory ability.

In sum, there is converging evidence from both reaction time studies and neurological studies implicating working memory as a component of successful deception. However, only one theory of deception takes advantage of the presumed involvement of working memory in deceptive responses – the cognitive load approach.

The Cognitive Load Approach to Deception

The premise of the cognitive load approach is that lying is more cognitively demanding than truth telling because of the various mental processes involved (e.g., inhibiting the truth, creating a plausible lie, and being cognizant of one's mannerisms Vrij et al., 2006; Vrij, Fisher, et al., 2008). Thus, introducing a secondary task in addition to the already cognitively demanding task of lying will impose enough cognitive load on the liar to deplete the limited cognitive resources available to succeed in lying. This paradigm for detecting deception has been used in several research studies.

One of the first studies to employ the cognitive load paradigm was conducted by Vrij and colleagues (2008). Participants were randomly assigned to either being truth tellers or liars. The truth tellers were instructed to play Connect Four with a confederate. At some point during the game, the Connect Four players were interrupted by a second confederate who entered the room to recover his wallet; at which point, he discovered that money had been stolen from his wallet. The liars, on the other hand, did not participate in the Connect Four event. Instead, the liars were instructed to take money from the wallet in the room but deny ever doing so when interviewed about the missing money. The liars were provided the cover story of playing a game of Connect Four so that the interviewer, who was blind to the conditions and not one of the two confederates in the Connect Four scenario, would not be able to easily determine who was in the truthful and deceptive conditions. During the interview, half of the participants were instructed to recount the events that transpired in the room from beginning to end (i.e., forward order). The other half of participants were asked to recount the events in the room in the reverse order, meaning they described their accounts from the end to the beginning. For instance, a participant in the forward order condition would state that she was instructed to play Connect Four; then, a few minutes later, another gentleman entered the room looking for his wallet. When he found his wallet, he discovered that money was stolen. In contrast, a participant in the reverse-order condition would state that she recalls that the last thing that happened was that a gentleman discovered that money was stolen from his wallet. Before that, he walked into the room looking for his wallet. Before the gentleman walked into the room, she had been playing Connect Four for several minutes. Lastly, everything started when she was instructed to play Connect Four.

The results indicated that liars showed significantly more signs of cognitive load (i.e., slower speech rate, more speech hesitations, and more speech errors) than truth tellers. Additionally, when all the interviews were coded by two blind and independent judges, liars’ speech in the reverse-order condition contained significantly fewer auditory details, fewer contextual embedding details, and more details of thoughts in their descriptions than did truth tellers, which were all considered indicators of cognitive load.

Thus, inducing additional cognitive load on liars appeared to overload participants' limited amount of cognitive resources.

A thorough review of the deception literature has revealed that while working memory is commonly implicated as a possible mechanism for detectable differences in truth tellers and liars, no study to date has directly tested the relationship between working memory and deception ability. The studies that have directly related cognitive effort to deception ability have been those that used eye tracking methodology. Results of these eye tracking studies have shown that generating a lie required greater cognitive effort as evidenced by increased pupil size (Dionisio et al., 2001). The proposed study seeks to specify that greater cognitive effort during deception found in eye tracking studies is associated with individual differences in working memory.

Eye Tracking Studies of the Cognition of Deception

While meta-analysis of people's ability to detect deception showed that gaze aversion is not a cue to reliably discriminating between truths and lies (DePaulo et al., 2003), the relatively unexplored area of deception research investigating specific, operationally-defined types of eye movements (such as blink rate and pupil diameter) using eye tracking, has found significant differences between truth tellers and liars. For example, Leal and Vrij (2008) randomly assigned participants to either a truth or lie condition. Those in the truth condition were instructed to go about their normal business for 10 minutes. Those in the lie condition were instructed to steal an exam from a professor's office, then deny having done so when interviewed. During the interview phase, a researcher blind to the study conditions interviewed all the participants about what they had done since starting the experiment. During the interview, participants' blink rate was recorded. Results showed that during deception, blink rate significantly decreased compared to baseline. Additionally, liars' blink rate showed a compensatory effect in the time period immediately after telling a lie. That is, immediately after a lie, blink rate significantly increased. The researchers posit that since deception is cognitively demanding, blink rate decreases to allow for more cognitive resources to be allocated to successful deception. However, when the deception is completed, cognitive resources are re-allocated back to blinking. Research on the relationship between blink rate and cognitive processing supports Leal and Vrij's (2008) conclusion that blink rate decreases when cognitive processing increases (Bagley & Manelis, 1979; Drew, 1951; Goldstein, Bauer, & Stern, 1992; Holland & Tarlow, 1972, 1975).

Moreover, several studies reveal that pupil diameter increases during deception in comparison to truth telling. For example, Webb, Honts, Kircher, Bernhardt, and Cook (2009) randomly assigned participants to either the deception or truthful condition. Participants in the deception condition were instructed to steal money from an office, then deny having done so. Participants in the truthful condition were told that some participants in the study were instructed to steal money from an office, but they were not to commit the crime. Afterwards, all participants were interviewed using portable eye-tracking goggles. The results revealed that pupil diameter was highly correlated with deception (r = .61).

Another example of research showing the relationship of pupil dilation to cognitive load is Dionisio, Granholm, Hillix, and Perrine (2001). The researchers instructed participants to learn a list of general knowledge questions (e.g., the colors of the American flag) and memorize a paragraph-long story. All participants were then seated at a desk-mounted eye tracker connected to a computer screen which prompted participants to lie or tell the truth to the questions played to participants on a recording synced with the truth and lie prompts. For instance, the computer would prompt the participant to tell the truth while the question “What are the colors of the American flag?” was played through headphones. After 15 seconds, the computer prompt would change while the next pre-recorded question was played through headphones. The results revealed that deceptive responses elicited significantly increased pupil size than truthful responses for both general knowledge questions and questions about a memorized story. The increased pupil dilation found during deceptive responses in several studies is posited to be due to the relationship of pupil size in cognitive processing such that pupil diameter increases when cognitive processing increases (Dionisio et al., 2001; Granholm, Asarnow, Sarkin, & Dykes, 1996; Lubow & Fein, 1996; Szulewski, Roth, & Howes, 2015; Verney, Granholm, & Marshall, 2004). Given the relationship of pupil size and blink rate with cognitive processing and deception, pupil size and blink rate will be further explored in the present study to investigate the role of working memory as a cognitive mechanism of deception.

Hypotheses/Predictions

It is presumed that differences between truth tellers and liars’ eye movement are due to the fact that deception requires more cognitive processing as pupillary responses and blink rate are indicative of the amount of cognitive processing needed to complete a task (Bagley & Manelis, 1979; Beatty, 1982; Cook et al., 2012; Dionisio et al., 2001; Drew, 1951; Goldstein et al., 1992; Holland & Tarlow, 1972, 1975; Karatekin, Couperus, & Marcus, 2004). However, no study to date has attempted to probe for a specific cognitive mechanism driving these differences between truths and lies. As such, the present study seeks to investigate whether the difference in eye movement between deception and truth telling is related to one's working memory span. Specifically, working memory ability is predicted to mitigate the cognitive load inherent in deception. Thus, the independent variables are veracity (i.e., baseline, truth, and lie statements) and working memory span. Veracity will be a within-subjects variable and working memory span will be treated as a continuous variable. The dependent variables will be eye-tracking measures of cognitive load as described previously (Dionisio et al., 2001; Vrij et al., 2010; Walczyk, Griffith, et al., 2013): pupil diameter and blink rate.

It is predicted that when participants are lying, they will exhibit more signs of increased cognitive processing than when they are telling the truth (Vrij, Fisher, et al., 2008; Walczyk et al., 2003; Zuckerman et al., 1981). Specifically, when participants are lying, they will show decreased blink rate and increased pupil diameter relative to when they are telling the truth or during baseline. Since prior research implicates working memory as a cognitive mechanism necessary for successful deception, the increased cognitive processing (as measured by blink rate and pupil size) will be related to working memory span (as measured by the OSPAN).

In terms of working memory capacity, since the cognitive load paradigm assumes that cognitive resources are limited (Vrij, Fisher, et al., 2008), it is predicted that those with higher working memory capacity will have more cognitive resources to draw upon when under cognitive load than participants with lower working memory capacity. Consequently, participants who are low in working memory capacity will show increased signs of cognitive demand overall (i.e., decreased blink rate and increased pupil dilation) than participants who are high in working memory capacity. Thus, combining working memory capacity with deception, it is predicted that during their deceptive statements, participants who are high in working memory capacity will show fewer signs of cognitive load than those who are low in working memory capacity.

CHAPTER TWO

Methods

Participants

Participants were Introductory Psychology students from Idaho State University completing research for course credit. It was estimated based off of prior literature on eye tracking studies of deception and cognitive load (e.g., Chen & Epps, 2014; Pittarello et al., 2015; Walczyk, Griffith, et al., 2013; Webb et al., 2009) utilizing a within-subjects design that 60 participants will be required to have adequate power (95%) to conduct multiple regression analyses for a two predictor model, veracity (baseline, truth, and lie) and working memory span, on the dependent variables of blink rate and pupil diameter (total of 2 multiple regression analyses; one for each dependent variable), collected during the truth statement and again during the lie statement.

In addition to course credit, participants were informed that they could be entered into a drawing for a $50 gift card to a local restaurant if they were able to successfully deceive the computer. In actuality, all participants were entered into the drawing. Additional compensation for participation beyond course credit was necessary since the deception literature has shown that the presence of additional stakes for successful deceit encouraged participants to deliver as much effort as they normally would (Bond & DePaulo, 2006; Carlucci, Compo, & Zimmerman, 2013; Caso, Gnisci, Vrij, & Mann, 2005). Thus, providing additional compensation is standard practice in deception research (e.g., Fenn, Blandón-Gitlin, Coons, Pineda, & Echon, 2015; Leal et al., 2010).

Materials

Replicating Fenn, Blandón-Gitlin, Coons, Pineda, and Echon (2015), a controversial topics questionnaire was developed from a Gallup poll of controversial topics (e.g., abortion; see Appendix A; Saad, 2010). Participants rated each divisive topic on a Likert-type scale (1 = strongly agree, 7 = strongly disagree). The questionnaire also asked participants to answer how strongly they personally felt about each issue on a scale of 1 (not at all) to 7 (very strongly) to control for any covariates and confounds related to the magnitude of how they felt about each topic. The experimenter selected a topic that the participant felt strongly for or against (i.e., the lowest and highest numbers on the Likert-scale for strongly agree and strongly disagree) and was the most personally relevant (i.e., 1 on the Likert scale for personal relevance). This selected topic was the topic the participant lied and told the truth about during the eye-tracking phase.

The operation span (OSPAN; a measure of working memory capacity) was conducted through E-Prime 2.0 on a Toshiba Satellite C55-B5296 laptop computer. The OSPAN task used in the current study was a modification of the OSPAN developed by Turner and Engle (1989) used by Turley-Ames and Whitfield (2003). Participants had seven seconds to solve an elementary math equation (e.g., (2 +1) x 2 = ___?) and read aloud a word that they recalled on a piece of paper at the end of each set (e.g., “chair”). Each component of the equation was presented one at a time in a moving widow (Turley-Ames & Whitfield, 2003); participants controlled the speed of the appearance of each element with a keyboard button press. If the participant did not solve the equation and read the to-be-remembered word in seven seconds, the computer automatically progressed to the next equation. Participants were given a practice OSPAN to familiarize themselves with the task. Once participants completed the OSPAN and passed the inclusion criteria (i.e., at least 3 out of the last 4 math-word operation blocks), participants proceeded to the actual OSPAN task which began with blocks of two math-word operations and increased to blocks of six math-word operations for a total of 15 blocks. Overall, the OSPAN task took about 20 minutes to complete.

All participants were instructed to use a rehearsal strategy during administration of the OSPAN. Turley-Ames and Whitfield (2003) have found that this procedure provided a valid and reliable measure of working memory span. Thus, during the OSPAN task, participants were instructed to repeat the to-be-remembered words aloud as many times as possible before continuing to the next math problem. As additional to-be-remembered words appeared for each set, participants would repeat aloud not only the new to-be-remembered word, but also the previous to-be-remembered words in each set.

The procedure for the deception task was an adaptation of the interview procedure used by Fenn and colleagues (2015) and Leal, Vrij, Mann, and Fisher (2010). Participants were asked to provide a truth statement and a lie statement (1 minute for each statement) for the same controversial topic selected by the experimenter as mentioned earlier. Thus, the truthful statement was the participant's actual belief about the topic, while the deceptive statement was the opposite of the participant's belief about the topic. The researcher would prompt the participant for both truth and lie statements by saying, "I hear that you are for/against __________. Tell me how you developed this opinion. Please start by restating this opinion and talk for about 1 minute." Whether the participant told the truth or lie first was counterbalanced to prevent order effects. Participants were directed to talk aloud for one minute for each statement. If participants stopped speaking before the one-minute mark, the researcher would prompt the participant to continue (e.g., “What aspects of the issue were critical in forming this opinion?”, “Please tell me more.”). While participants were providing truthful and deceptive statements, eye movements were recorded using an SR Research EyeLink 1000 desk-mounted eye tracker. All participants, regardless of condition, were instructed to maintain their gaze on the fixation cross presented at the center of the computer screen.

Procedure

After participants provided their informed consent for participating in the study, they completed the demographics questionnaire (see Appendix B) and filled out a questionnaire (see Appendix A) asking how strongly they felt about the controversial topics on a scale of 1 (strongly disagree) to 7 (strongly agree). Participants also indicated how strongly they personally felt about the controversial topics on a scale of 1 (not at all) to 7 (very strongly) to control for the magnitude of their response to the issue at hand. The experimenter selected the one topic the participant strongly agreed/disagreed with at the highest magnitude for use during the deception task. In the case of a participant ranking several topics equally highly on opinion (i.e., strongly agree/disagree) and personal relevance, the experimenter randomly selected a topic from those of equal opinion and personal relevance ranking.

After completing the controversial topics questionnaire (see Appendix A and B), participants moved on to the operation span (OSPAN), a commonly used measure of working memory span (Turley-Ames & Whitfield, 2003; Turner & Engle, 1989). Once participants completed the OSPAN, they then proceed to the deception task in the eye tracker (explained previously). While participants were providing truthful and deceptive statements, eye movements were measured using an SR Research EyeLink 1000 desk-mounted eye tracker. For each individual participant, the eye tracker was calibrated to precisely track the participant's right pupil. Calibration was conducted using a nine-point dot matrix where each participant was instructed to look at each dot as they appear one by one on the screen. Once the eye tracker algorithm determined that pupil tracking was within the appropriate window to continue, the experimenter started the deception task. After completing a baseline measurement of participants' pupil dilation and blink rate, participants completed both truth and lie statements. Afterwards, they were debriefed, thanked, and compensated for their participation.

Data Analysis

The predictor variables for the current study were veracity (i.e., baseline vs. truth vs. lie; within-subjects variable) and working memory span (continuous variable; between-subjects variable). The outcome variables were blink rate and pupil diameter (i.e., indicators of cognitive load). To specifically describe how data were evaluated, each hypothesis is listed and followed by a data analysis plan.

Hypothesis 1: Lying is more cognitively loading than truth telling. Participants were predicted to show increased signs of cognitive load (i.e., decreased blink rate and increased pupil diameter) when comparing deceptive statements to truthful and baseline statements.

Hypothesis 2: Working memory span may compensate for the effect of cognitive load. As such, participants with higher working memory capacity should have more cognitive resources to draw upon when under cognitive load than participants with lower working memory capacity. Thus, participants with a lower working memory capacity should show increased signs of cognitive load (i.e., decreased blink rate and increased pupil dilation) when compared to those with higher working memory spans.

Hypothesis 3: An interaction between working memory span and veracity on cognitive load was predicted. Working memory and veracity were predicted to interact such that participants with a higher working memory capacity would show fewer signs of cognitive load when lying compared to participants with a lower working memory capacity.

All three hypotheses were investigated using two multiple regression models, one regression model for each outcome variable (i.e., blink rate and pupil diameter). Both models consisted of the predictors working memory (continuous variable) and veracity (baseline, truth, and lie; within-subjects variable). The main effect of veracity will answer Hypothesis 1. The main effect of working memory will answer Hypothesis 2. The interaction of working memory and veracity will answer Hypothesis 3.

CHAPTER THREE

Results

Demographics

While 78 participants completed the study, 60 were included in the final analyses. Eighteen participants were not included in the final analyses because eight failed the inclusion criteria for the operation span task, five spoke English as a second language, 2 had validation/calibration errors in the eye tracker, one did not follow directions in filling out the controversial topics questionnaire, and one participant's eye tracker data was not recorded.

Participants' age ranged from 18 to 44 years old (M = 21.63, SD = 5.30). Working memory scores did not differ by gender [$t(58) = .17$, $p = .87$; Female: $n = 34$, Male: $n = 26$]; education [$F(4, 55) = .41$, $p = .80$; Freshmen: $n = 29$, Sophomore: $n = 18$, Junior: $n = 5$, Senior: $n = 7$, Other: $n = 1$]; nor ethnicity [$F(4, 55) = .78$, $p = .55$; African-American: $n = 1$, Caucasian: $n = 48$, Hispanic/Latino: $n = 6$, Asian-American: $n = 1$, Other: $n = 4$]. Participants' working memory scores also did not differ by psychological condition [$t(58) = .012$, $p = .99$; endorsed having a diagnosed psychological condition: $n = 13$, did not endorse having a psychological condition: $n = 47$] nor learning difficulty [$t(58) = .33$, $p = .74$; endorsed having a learning difficulty: $n = 1$, did not endorse having a learning difficulty: $n = 59$].

Manipulation Checks

Working memory differences at baseline. One-way ANOVAs were conducted to assess whether working memory group differences existed at baseline measurements for pupil dilation and blink rate. These analyses were conducted to ensure that working memory groups were not different from the outset before engaging in the truth and lie task. If such differences existed at baseline, then the results of the main analyses would be called into question. Blink rate was measured as number of blinks per minute; pupil dilation was measured in unconverted units provided by the SR Research eye tracker program. These will be converted later into millimeters for publication purposes.

Working memory groups were created by conducting a tertiary split of OSPAN scores. Thus, participants were grouped into low (OSPAN scores 28-42; $n = 30$), medium (OSPAN scores 43-48; $n = 21$), and high (OSPAN scores 49-60; $n = 19$) working memory span categories. These scores are consistent with extant literature of normed, tertiary-split operation span scores (Redick et al., 2012). A one-way ANOVA revealed that there were no working memory group differences for both pupil dilation [$F(2, 58) = 1.40$, $p = .26$; see Figure 1] and blink rate [$F(2, 59) = .46$, $p = .64$; see Figure 2] at baseline.

Order effects. The order of truth and lie statements was counterbalanced across participants to better ensure that any differences between truth and lie statements were due to cognitive load rather than an effect of order of presentation. Averaging together all veracity conditions (i.e., baseline, truth statement, lie statement), independent-samples *t*-tests revealed no significant differences in pupil dilation [$t(177) = 1.40$, $p = .16$] nor blink rate [$t(178) = -.51$, $p = .61$] between conditions where the truth statement came first or where the lie statement came first (see Figures 3 and 4). Furthermore, when considering only baseline trials, independent-samples *t*-tests revealed no significant differences in pupil dilation [$t(57) = 1.24$, $p = .22$] nor blink rate [$t(58) = -.52$, $p = .61$] between conditions where the truth statement came first nor where the lie statement came first (see

Figures 5 and 6). Thus, cognitive load effects did not differ due to order of statement presentation.

Topics and prompts. A chi-square test of goodness of fit revealed that some topics were asked more than others [$\chi^2(14) = 39$, $p < .001$]. While the expected frequency was less than five (expected $n = 5$) for each topic, Howell (2014) states that large tables, such as the one conducted with 16 topics, do not violate the chi-square assumption of expecting 5 observances per cell since large tables will naturally have fewer than 5 observances per cell. Looking at the frequency table (see Table 1), the topic "People should be allowed to have gay and/or lesbian relationships" was selected the most often ($n = 13$) whereas all other topics were selected less frequently. For topics that were strongly endorsed for both opinion and personal relevance, participants evenly endorsed strongly agreeing ($n = 30$) and strongly disagreeing ($n = 27$) with selected topics. Furthermore, most participants ($n = 48$) endorsed the selected topic as very personally relevant (see Table 2).

The number of prompts the experimenter had to use to keep participants speaking the full minute for each statement was collected. In general, the mean number of prompts for truths ($M = 1.23$, $SD = 1.27$) and lies ($M = 1.22$, $SD = 1.39$) were not significantly different, $t(59) = .13$, $p = .90$ (see Figure 7). However, veracity order effects were present when truth statements came first for number of prompts during truth statements, $t(58) = 3.05$, $p = .003$. The mean number of truth prompts were significantly lower when truth statements were told after lie statements ($M = .77$, $SD = 1.07$) than when truth statements were told first ($M = 1.70$, $SD = 1.29$; see Figure 8). There was no veracity order effect for number of prompts during lie statements, $t(58) = -.28$, $p = .78$ (see Figure 9). Moreover, working memory group did not significantly affect the number of prompts in either truth [$F(2, 57) = .66$, $p = .52$; see Figure 10] or lie statements [$F(2, 57) = .46$, $p = .64$; see Figure 11].

Regression

To investigate the effect of working memory and veracity on blink rate, a hierarchical multiple regression model was conducted. The first level included working memory performance and veracity. The second level included working memory performance, veracity, and the interaction of working memory performance and veracity. These models were used to analyze the prediction to average pupil dilation and blink rate, separately.

Average pupil dilation. For average pupil dilation, the first level model was significant, $R^2 = 0.17$, $F(2, 178) = 17.71$, $p < .001$, where working memory performance [$B = 25.08(7.07)$, $p < .001$] and veracity (i.e., baseline, truth, lie; $B = 271.67(56.67)$, $p < .001$) were both significant predictors. The second level model was also significant, $R^2 = 0.17$, $F(3, 178) = 11.82$, $p < .001$; however, the ΔR^2 for model 2 was not significant, $\Delta R^2 = 0.001$, $F(1, 175) = .19$, $p = .66$. The ΔR^2 for model 1 was significant, $\Delta R^2 = 0.17$, $F(2, 176) = 17.71$, $p < .001$. Thus, the main effect of working memory performance and veracity appear to drive the prediction of pupil dilation more than the interaction of working memory performance and veracity (see Table 3).

Blink rate. For blink rate, the first level model was significant, $R^2 = 0.14$, $F(2, 179) = 14.62$, $p < .001$, where veracity (i.e., baseline, truth, lie; $B = 7.44(1.46)$, $p < .001$) was a significant predictor, but working memory performance [$B = -.32(.18)$, $p = .08$] was not. The second level model was significant, $R^2 = 0.15$, $F(3, 179) = 9.93$, $p < .001$;

however, the ΔR^2 for model 2 was not significant, $\Delta R^2 = 0.003$, $F(1, 176) = .61$, $p = .44$. Thus, the main effect of veracity appears to drive the prediction of blink rate more than the interaction of working memory performance and veracity (see Table 3).

MANOVA

MANOVA was also conducted to investigate which groups were responsible for the effects seen in the multiple regression results, especially since baseline was included as a level of veracity in the present study. A baseline condition is necessary, especially in an eye tracking study, to act as a control to determine if eye movement patterns differ at the outset from the rest of the experiment. If there is a difference in the dependent variables to begin with, the subsequent results would be due more to differences in the sample rather than differences due to the independent variables. Furthermore, for deception studies in particular, it is important to verify that truth telling acts as a control (as most deception studies conceptualize truth telling as equitable to a baseline without necessarily empirically testing that assumption; e.g., Mann et al., 2012) or if truth telling is different from a more neutral task. In the present study, the baseline measurement allows for testing whether participants' pupil dilation and blink rate differ when sitting quietly looking at a fixation cross compared to truth telling and lying.

Before conducting the MANOVA, assumption tests were conducted. The Box's M test was not significant [Box's M = 25.15, $F(24, 86681.20) = 1.00$, $p = .46$], meaning that the covariance matrixes were equal; thus, the assumption of homogeneity of covariances was held. The Bartlett's test was significant [$\chi^2(2) = 1028.20$, $p < .001$], meaning that the dependent variables were correlated with each other. The Levene's test was also non-significant for both pupil dilation [$F(8, 170) = .62$, $p = .76$] and blink rate

[$F(8, 170) = 1.95$, $p = .06$], meaning that each dependent variable had equal error variance across groups. Taken together, all MANOVA assumptions were met; therefore, MANOVA was an appropriate statistical test (Tabachnick & Fidell, 2013) with respect to the variables of interest in the present study.

A MANOVA was conducted after creating a tertiary split of OSPAN scores grouped into low (OSPAN scores 28-42; $N = 30$), medium (OSPAN scores 43-48; $N = 21$), and high (OSPAN scores 49-60; $N = 19$) working memory span categories (e.g., Daneman & Carpenter, 1980; Turley-Ames & Whitfield, 2003). The main effect of working memory was significant, Wilk's $\lambda = .91$, $F(4, 338) = 4.34$, $p = .002$, partial $\eta^2 = .05$. The main effect of veracity was also significant, Wilk's $\lambda = .72$, $F(4, 338) = 14.78$, $p < .001$, partial $\eta^2 = .15$. However, the interaction between working memory and veracity was not significant, Wilk's $\lambda = .99$, $F(8, 338) = .32$, $p = .96$, partial $\eta^2 = .008$ (see Table 4).

Since main effects in the MANOVA model were significant, univariate analyses of working memory and veracity were conducted using a Bonferroni-adjusted significance value of $p < .03$ (Tabachnick & Fidell, 2013). For working memory, pupil dilation was significant [$F(2, 179) = 4.45$, $p = .01$, partial $\eta^2 = .05$], but blink rate was not [$F(2, 179) = 3.61$, $p = .03$, partial $\eta^2 = .04$]. For veracity, both pupil dilation [$F(2, 179) = 15.93$, $p < .001$, partial $\eta^2 = .16$] and blink rate [$F(2, 179) = 23.54$, $p < .001$, partial $\eta^2 = .22$] were significant (see Figures 12 and 13).

Bonferroni-adjusted post-hoc analyses were conducted to determine which levels of each independent variable were significant for which specific dependent variable. Since both working memory and veracity consisted of three levels (i.e., low, medium, high working memory span and baseline, truth, lie veracity condition), all post-hoc tests were compared to a Bonferroni adjusted significance value of $p < .0083$ (Tabachnick & Fidell, 2013). For working memory, no pairwise comparisons were significant at the .0083 alpha level. For veracity, baseline-truth and baseline-lie pairwise comparisons were significant at the $p < .001$ level for both pupil dilation and blink rate (see Figures 12 and 13). In the baseline-truth comparison, mean pupil dilation was significantly higher during truth statements (*M* = 4618.36, *SD* = 79.86) than baseline (*M* = 4048.96, *SD* = 80.55). Similarly, mean blink rate was significantly higher during truth statements (*M* = 38.02, *SD* = 1.96) than baseline (*M* = 20.34, *SD* = 1.98). In the baseline-lie comparison, mean pupil dilation was significantly higher during lie statements (*M* = 4588.843, *SD* = 79.855) than baseline (*M* = 4048.96, *SD* = 80.55). Similarly, mean blink rate was significantly higher during lie statements (*M* = 35.488, *SD* = 1.96) than baseline (*M* = 20.34, *SD* = 1.98). These results indicate that pupil dilation and blink rate are different between quietly looking at a fixation cross and telling the truth. However, counter to prior assumptions, lies and truths were not significantly different from each other on either cognitive load measurement.

CHAPTER FOUR

Discussion

The present study sought to investigate the role of working memory in managing the cognitive load of deception. As such, both veracity and working memory were significant predictors of pupil dilation while only veracity significantly predicted blink rate. However, post-hoc tests show that differences in veracity and working memory were not necessarily in the direction predicted. The following discussion will examine potential explanations for why results did not follow predicted directions. First, rationales for why truth telling appears to be as cognitively loading as lying will be discussed within the purview of extant literature and potential future directions described. Second, rationales for the lack of significant post-hoc group differences in working memory span will be discussed within the purview of extant literature and potential future directions described.

Differentiating Between Truths and Lies

The cognitive load approach asserts that liars should experience more cognitive load than truth tellers (Vrij, Fisher, et al., 2008). However, the present study observed that neither lie statements nor truth statements induced a significantly differential amount of cognitive load to discriminate between truths and lies. In fact, the main effect of veracity appears to be driven by the comparison of truths and lies to baseline as evidenced by the MANOVA post-hoc tests. Since truth statements were as cognitively loading as lie statements, it is possible that the deception task induced cognitive overload which created a ceiling effect such that truths were just as cognitively loading as lies rather than increasing the difference between lies and truths as expected. Per the logic of the cognitive load approach, truths should require less cognitive effort relative to lying (Walczyk, Igou, et al., 2013). Additionally, since topics were high in personal relevance, participants should have information readily available to facilitate the expression of his/her true opinions (Leal et al., 2010).

In a similar study investigating the premises of the cognitive load approach on general eye movement and pupil dilation using eye tracking methodology, Walczyk and colleagues (2012) also failed to find support for greater pupil dilation for lies relative to truths. The authors posited that inducing additional cognitively-loading procedures (in their study, maintaining eye contact throughout all statements) to the task of lying may have “overshadowed any modest cognitive load effects due to lying (p. 17),” echoing Bond and DePaulo's (2006) claim that cues to deception have small to moderate effect sizes.

In the present study, the Devil’s advocate procedure of requiring participants to endorse the opposite of their own strongly held beliefs (i.e., the lie statement), which is a questioning technique shown to induce cognitive load (Fenn et al., 2015; Leal et al., 2010), could have induced the same cognitive overload posited by Walczyk and colleagues (2012). Also, participants were instructed to lie and tell the truth while maintaining focus on the fixation cross in the middle of the screen which Walczyk and colleagues (2012) used to induce additional cognitive load. The cognitive overload of asking participants to both lie and tell the truth about a strongly held opinion while maintaining focus on a fixation cross may explain why truth telling and lying were equally difficult for participants in the present study. Future research using less controversial or neutral topics may produce the predicted pupil dilation results.

Alternatively, while the mean number of prompts did not reveal statistically significant differences in most cases, the mean number of prompts during truth statements was significantly higher when truth statements were told first as opposed to when truth statements were told second (i.e., after the lie statement). However, there were no order effects for number of prompts during lie statements. These results may indicate why truth telling was as cognitively loading as lying. The underlying assumption of the Devil's advocate approach to deception is that lying about one's own opinion requires first acknowledging one's opinion and then stating the opposite (Leal et al., 2010). The order effect in number of truth prompts may imply that, if participants used their own opinion as a basis for lying, lying about one's own opinion first primes all of the truthful reasons for one's own belief. In other words, lying first made telling the truth easier. This order effect implies that participants who told the truth first had a more difficult time than participants who told the truth second which could have contributed to increasing the cognitive load of the truth telling condition overall.

The low-stakes nature of the present study may also have contributed to the lack of discrimination between truths and lies through differences in pupil dilation and blink rate. Namely, if participants did not put forth effort to lie well, there were no consequences except for purportedly losing a chance to enter a raffle for a $50 gift card (in truth, all participants were entered into the raffle). Participants may not have considered loss of a raffle entry enough of a penalty to impact deception performance. As Caso, Gnisci, Vrij, and Mann (2005) show, participants lying under high stakes (i.e., participants were told that their statements would be evaluated by police officers) self-reported more indicators of cognitive load (i.e., feeling more tense, thinking harder, and exerting more effort in controlling themselves) than participants under low stakes. A high-stakes scenario, such as a mock-crime paradigm in which being caught lying would have ecologically valid repercussions, might have produced the expected blink rate and pupil dilation results. Since the cognitive load approach is predicated upon working memory as a mechanism for the differences in lies and truths, exploring the present study's working memory effects may assist in discovering why truths were as cognitively loading as lies.

Working Memory

Following the reasoning of the cognitive load approach to deception, working memory is assumed to mitigate the effect of cognitive load (Sporer & Schwandt, 2006, 2007); thus, those with high working memory should be better able to lie than those with low working memory. Thus, it was hypothesized that those with lower working memory would show increased signs of cognitive load when compared to those with high working memory capacity. However, the MANOVA post-hoc results of the present study indicate that those with high working memory showed more signs of cognitive load (i.e., decreased blink rate and increased pupil dilation) than those with low working memory (see Figures 12 and 13).

While this result was not predicted by the deception literature (as explained below), this result is in line with working memory literature that suggests that participants with high working memory perform worse under load than those with low working memory. For instance, when participants were asked to name as many animals as they could in 10-15 minutes, high working memory spans were able to name more than low working memory spans (Rosen & Engle, 1997). However, when participants were asked to name as many animals as they could in 10-15 minutes while engaging in a concurrent digit tracking task (i.e., pressing a button on a keyboard when an odd digit appeared on the screen three times in a row), high working memory spans recalled the same number of words as low working memory spans. Thus, only participants with high working memory span were affected negatively by the additional cognitive load of the dual-task paradigm. Further, since low working memory span performance was unaffected by additional cognitive load, the authors suggested that low working memory spans were already operating at floor. In other words, low working memory spans were not affected by the additional cognitive load because they were only utilizing relatively automatic processing (which would be unaffected by additional cognitive load) compared to high working memory spans utilizing strategic retrieval to generate more animal names (which would be affected by additional cognitive load; Kane & Engle, 2000). Thus, the present study's results may indicate that the premises of the cognitive load approach may need to be adjusted, especially in light of the cognitive load approach's common usage of the dual-task paradigm to induce cognitive load (see Vrij, Fisher, et al., 2008 and Walczyk, Igou, et al., 2013 for a review). Nevertheless, limitations in methodology in the present study cannot be discounted and are discussed below.

In the present study, blink rate was not statistically significantly different by working memory span group. However, high working memory spans showed the lowest mean blink rate overall (see Table 4 and Figure 13). It is possible that the blink rate data trending in the opposite direction as hypothesized may suggest that analyzing blink rate as a function of fluctuations over time are warranted (i.e., calculating blink rate in millisecond bins rather than throughout the whole statement). According to Fukuda

(2001) and Seymour, Baker, and Gaunt (2013), participants rarely blink when stimuli on a guilty knowledge test were presented, but blink rate significantly increased in the 50 milliseconds before participants responded to probe items (i.e., items in a mock crime scene that participants were instructed to lie about having any knowledge of). Both studies measured blink rate in 50 millisecond time bins to capture minute differences in blink rate as stimuli quickly appeared. Therefore, the present study may have concealed these subtle differences in task-evoked blink rate by measuring blink rate over the whole response interval (i.e., one minute) rather than in smaller time bins (i.e., 50 milliseconds).

Furthermore, Leal and Vrij (2008) showed that blinking behavior during deception also depends on timing. Participants were instructed to lie or tell the truth about participating in a mock crime (i.e., stealing an exam). Half of the participants were instructed to steal the exam and deny having done so (i.e., lie condition) while the other half were instructed to engage in normal behavior for 10 minutes (i.e., truth condition). Afterwards, all participants were interrogated by a condition-blind experimenter about the theft of the exam while blink rate was digitally recorded. Results showed that participants in the deception condition blinked less while they were lying, but blinking increased immediately after completing lie statements as if to compensate for the prior lack of blinking during lying.

With regard to the present study, it is possible that participants completed effortful lying before the trial period ended. In other words, participants could have stopped lying before the full one-minute period ended. The overall mean number of prompts and mean number of prompts during the lying statement were both nonsignificant by statement order and working memory span group, meaning that those results do not support the supposition that participants completed effortful lying before the statement interval ended. However, the experimenter recorded anecdotal notes when participants appeared to struggle to speak during the entire statement interval. Perhaps an investigation of differences in number of prompts by truth and lie statement per participant as opposed to group means would provide more quantitative support for the postulation that participants ended their lie statement earlier than the duration of the full trial period. If this speculation was empirically supported, the collected data could have contained both the decreased blink rate for lying and the increased compensatory blink rate after lying within the same one-minute period. Taken together, these findings suggest that an overall measurement of blink rate for the period in which participants were allowed to speak obfuscates the nuanced relationship of cognitive processing during deception as measured by blink rate. Future research should assess blink rate in smaller, millisecond time bins rather than as an overall average.

In terms of pupil dilation, those with higher working memory should have been able to manage the cognitive load of deception better than those with lower working memory, according to the logic of the cognitive load approach (Sporer & Schwandt, 2006, 2007). However, MANOVA post-hoc tests of group differences in working memory demonstrated that the mean pupil dilation was larger (i.e., greater cognitive load) in those with high working memory span than those with low working memory span (see Table 4 and Figure 7). Additionally, those with medium working memory span had the largest mean pupil dilation. Although the group means for pupil dilation were not statistically different, these data appear to suggest that having high working memory may not mitigate the effect of cognitive load. Nevertheless, research investigating individual differences in working memory, as it pertains to cognitive load and measured by pupil dilation, have shown that individuals lower on working memory exert more effort as indexed by increased pupil dilation (i.e., Heitz, Schrock, Payne, & Engle, 2008; Unsworth & Robison, 2014).

Another potential explanation for the lack of significant working memory span differences for pupil dilation could be that emotional arousal (through using controversial topics with a clear morality component) was confounded with cognitive processing. That is, increased pupil dilation may have captured both cognitive load and emotional arousal. Research has shown that pupil dilation is also related to emotional processing (e.g., Granholm & Steinhauer, 2004). For instance, Bradley, Miccoli, Escrig, and Lang (2008) found that pupil dilation increased when individuals viewed emotionally valanced photos (i.e., either pleasant or unpleasant) compared to neutral pictures. Since in the present study we asked participants to speak about topics that were purposely controversial (Saad, 2010), it is likely that pupil dilation indexed emotion as well as cognitive load which would explain why pupil dilation was not significantly different for truth telling and lying. Future research should consider the potential confound of emotional arousal when using controversial topics to induce cognitive load. Using neutral topics or stimuli would circumvent the confound of pupil dilation indexing emotional arousal as well as cognitive processing.

Conclusion

In conclusion, the present study investigated the role of working memory in managing the cognitive load of deception. Results were promising but mixed. Veracity and working memory were significant predictors of cognitive load. However, lies were not significantly more cognitively loading than truths, and those with high working memory span did not show the predicted pattern of blink rate and pupil dilation. The present study was a first step in investigating why the cognitive load approach to deception works; however, the results were not in the predicted directions. These results indicate that the role of working memory in deception production requires further investigation.

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Table 1

Frequency of Selected Topics

Topic	Frequency
People should be allowed to commit doctor-assisted suicide	2
People should be allowed to have gay and/or lesbian relationships	13
Women have the right to have an abortion	6
People have a right to have a baby outside of marriage	5
Sex between an unmarried man and unmarried woman is acceptable	3
There is nothing wrong about buying and wearing clothes made of animal fur	0
There is nothing wrong with conducting medical testing on animals	4
People should be allowed to gamble	1
There is nothing wrong about conducting medical research using stem cells obtained from human embryos	1
There is nothing wrong with cloning animals	1
The death penalty should be legal in all states	7
Divorce is acceptable	2
Suicide is acceptable	3
Cloning humans is acceptable	2
One husband having more than one wife at the same time (polygamy) is acceptable	2
Married men and women having an affair is acceptable	8

Table 2

Frequency of Opinion and Personal Relevance for Highly Endorsed Topics

Topic	N	Strongly Agree	Strongly Disagree	Very Personally Relevant
People should be allowed to commit doctor-assisted suicide	2	1	1	2
People should be allowed to have gay and/or lesbian relationships	13	12	1	12
Women have the right to have an abortion	5	2	3	4
People have a right to have a baby outside of marriage	4	4	0	3
Sex between an unmarried man and unmarried woman is acceptable	3	1	2	3
There is nothing wrong with conducting medical testing on animals	4	0	4	4
People should be allowed to gamble	1	1	0	1
There is nothing wrong about conducting medical research using stem cells obtained from human embryos	1	0	1	1
There is nothing wrong with cloning animals	1	1	0	1
The death penalty should be legal in all states	6	6	0	3
Divorce is acceptable	2	2	0	1
Suicide is acceptable	3	0	3	3
Cloning humans is acceptable	2	0	2	2
One husband having more than one wife at the same time (polygamy) is acceptable	2	0	2	2
Married men and women having an affair is acceptable	8	0	8	6
Total		30	27	48

Table 3

Hierarchical Regression of Pupil Dilation and Blink Rate.

Predictor Variables	*B*	*SE*	R^2	ΔR^2	*F*	ΔF
Pupil Dilation						
Step 1			.166		17.459***	
Working Memory	25.082**	7.080				
Veracity	269.194***	56.733				
Step 2			.166	.001	11.646***	.184
Working Memory	21.345	11.240				
Veracity	100.606	397.318				
Working Memory x Veracity	3.728	8.696				
Blink Rate						
Step 1			.150		15.597***	
Working Memory	-.322	.181				
Veracity	7.675***	1.449				
Step 2			.152	.003	10.555***	.551
Working Memory	-.157	.287				
Veracity	15.133	10.157				
Working Memory x Veracity	-.165	.222				

Note.
**p <.01
***p < .001

Table 4

MANOVA of Veracity and Working Memory on Pupil Dilation and Blink Rate

	Veracity							Working Memory						
	Baseline		Truth		Lie			Low		Medium		High		
	M	SD	M	SD	M	SD	F	M	SD	M	SD	M	SD	F
Pupil Dilation	4048.96	80.55	4618.36	79.86	4588.84	79.86	15.93***	4236.89	80.49	4567.12	77.87	4452.16	81.86	4.45*
Blink Rate	20.341	1.98	38.02	1.96	35.49	1.96	23.54***	33.40	1.98	33.52	1.91	26.93	2.01	3.61

Note. ****p* < .001, **p* < .01.

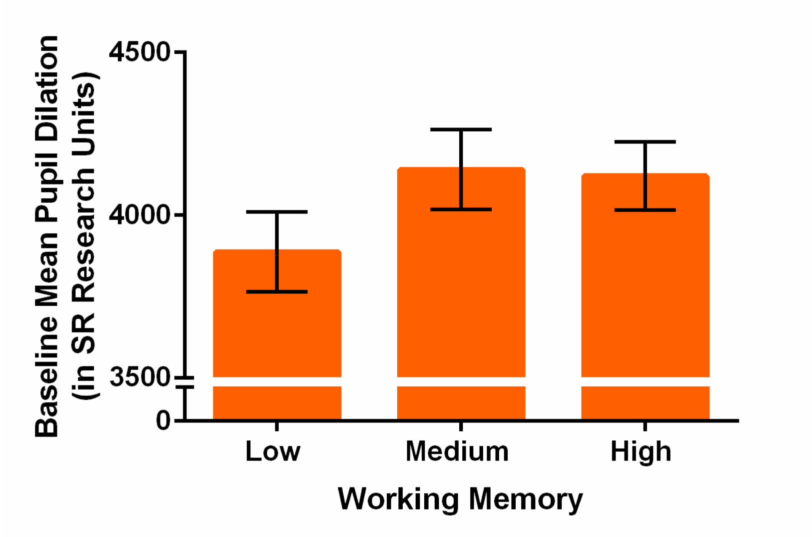

Figure 1. Working memory group differences for mean pupil dilation at baseline.

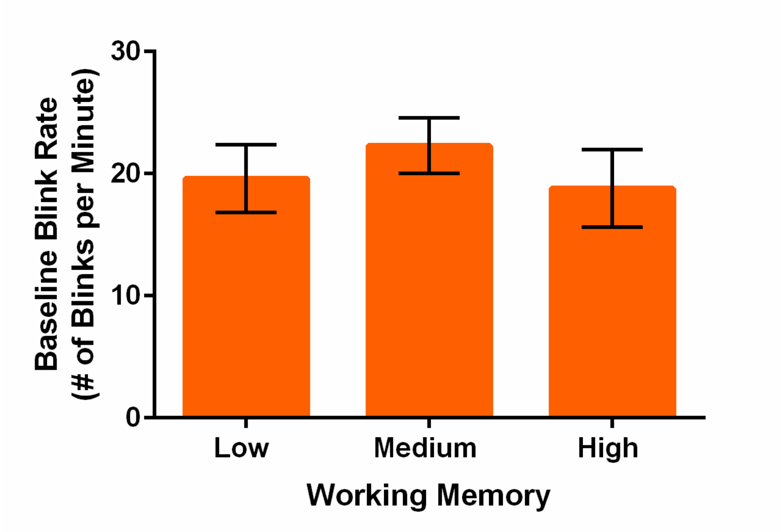

Figure 2. Working memory group differences for blink rate at baseline.

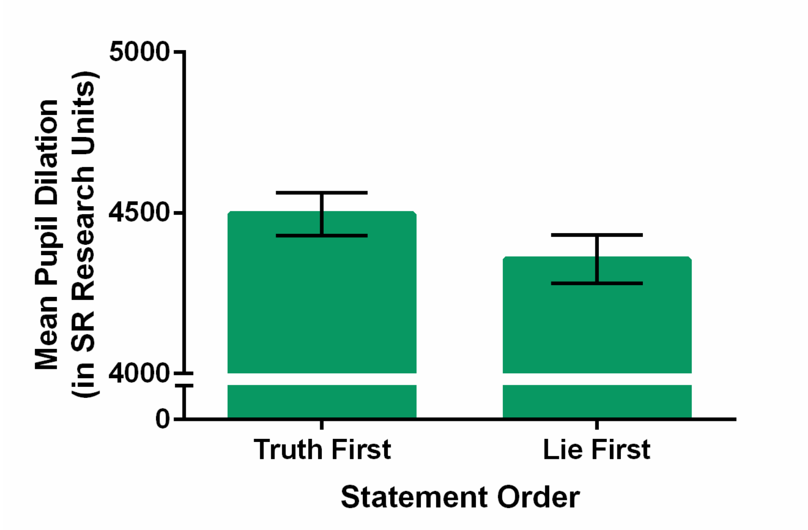

Figure 3. Statement order effect for mean pupil dilation averaged across all veracity conditions (i.e., baseline, truth, lie).

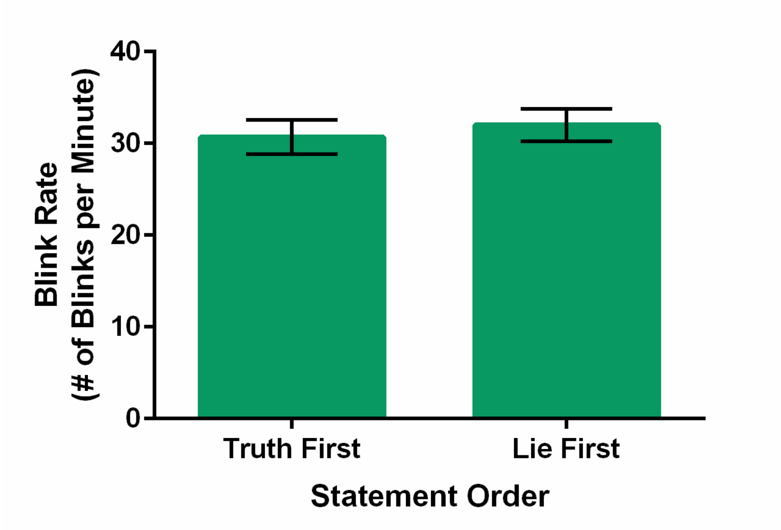

Figure 4. Statement order effect for blink rate averaged across all veracity conditions (i.e., baseline, truth, lie).

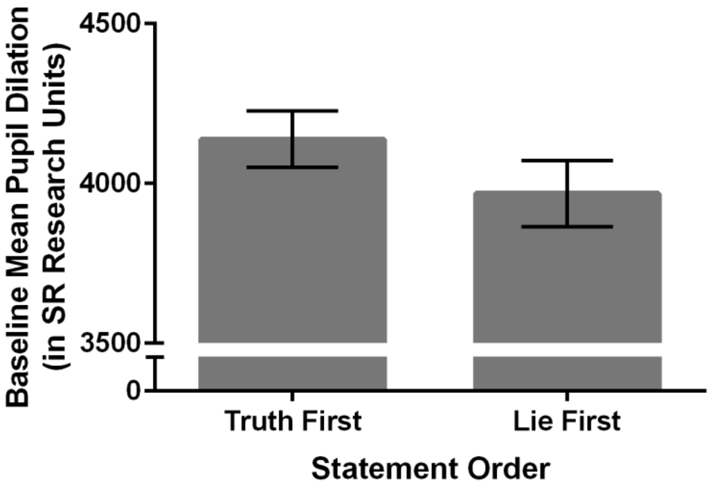

Figure 5. Statement order effect for baseline mean pupil dilation.

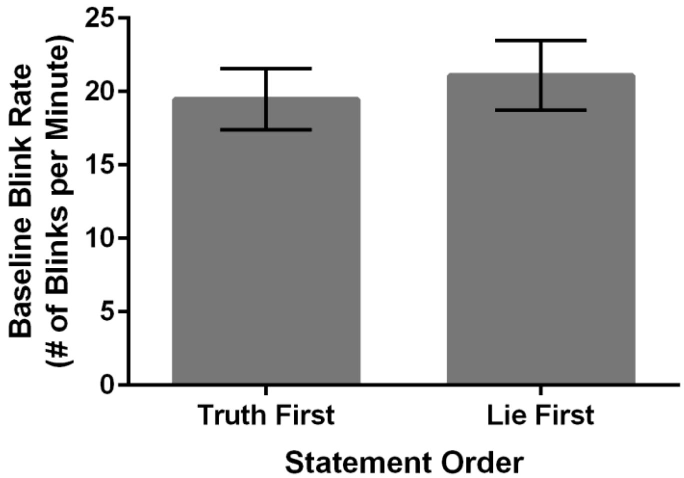

Figure 6. Statement order effect for baseline blink rate.

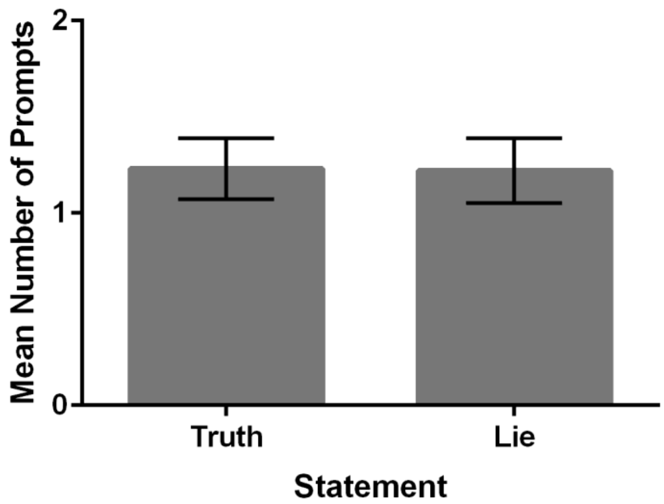

Figure 7. Mean number of prompts by statement type (i.e., truth or lie).

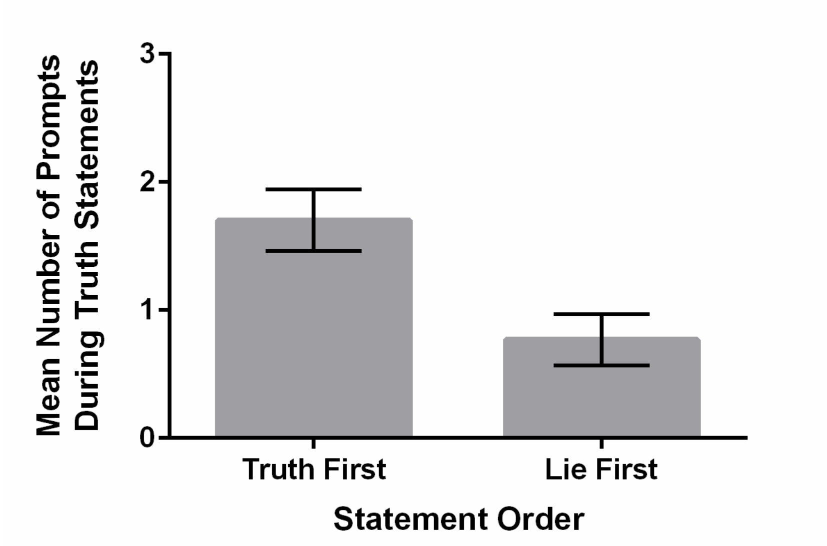

Figure 8. Statement order effect for mean number of prompts for truth statements.

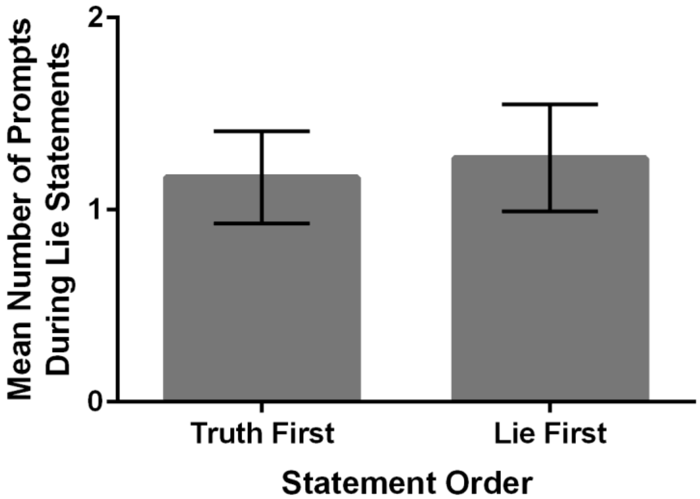

Figure 9. Statement order effect for mean number of prompts for lie statements.

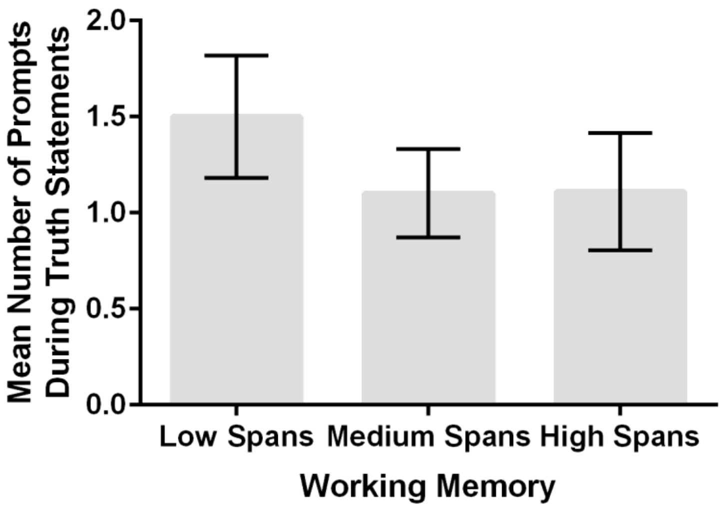

Figure 10. Mean number of prompts during truth statements by working memory span group.

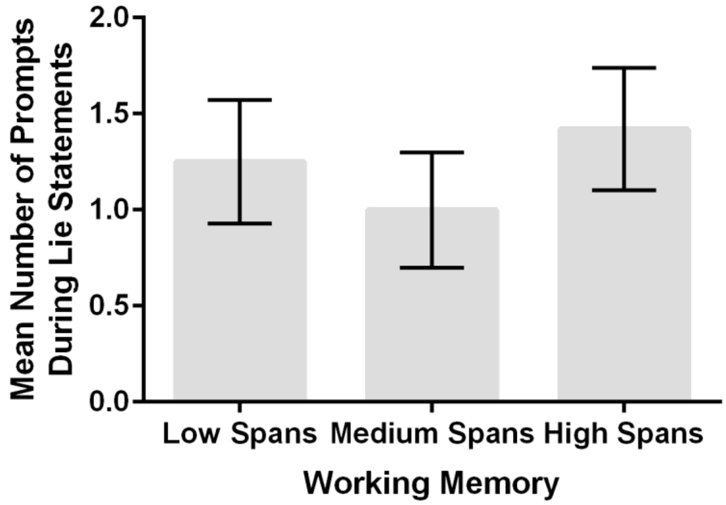

Figure 11. Mean number of prompts during lie statements by working memory span group.

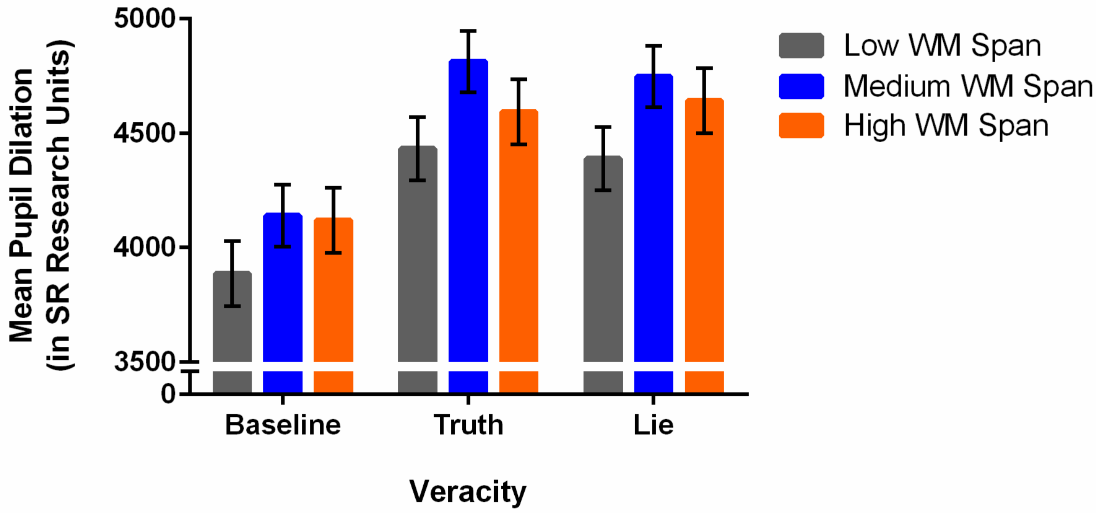

Figure 12. Univariate ANOVA of veracity by working memory on pupil dilation.

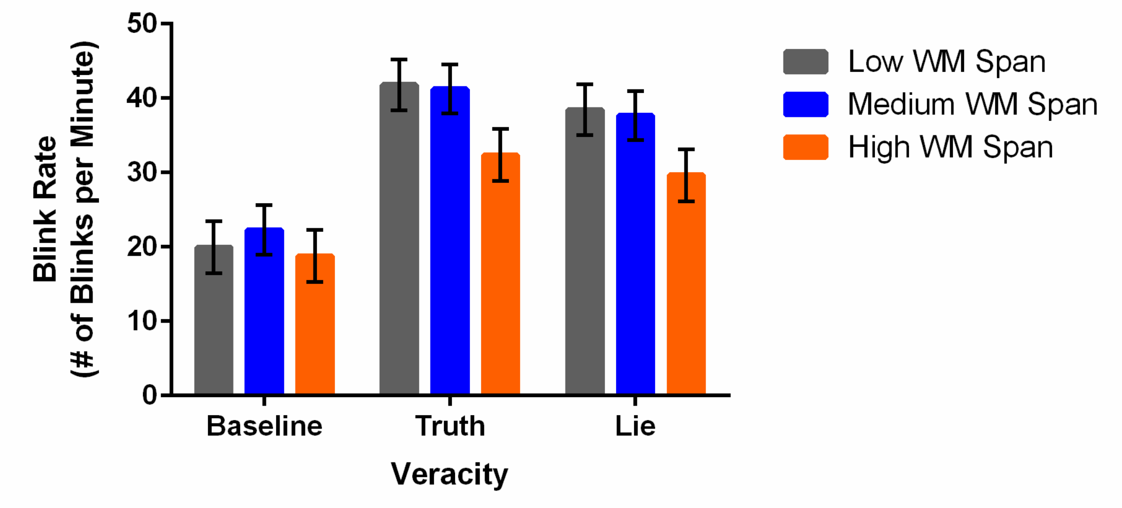

Figure 13. Univariate ANOVA of veracity by working memory on blink rate.

APPENDIX A

Social & Moral Issues Questionnaire

Below are moral issues based on a scale of 1-7. Please rank the following items according to the degree to which you either agree or disagree by highlighting the number that corresponds to your response. **Only rank an item with either 1 or 7 if you have a very strong opinion for or against.** There are no right or wrong answers, we are simply interested in your opinion.

1. People should be allowed to commit doctor-assisted suicide.

1----------------2----------------3----------------4----------------5----------------6----------------7
Strongly Agree Strongly
Disagree

How strongly do you personally feel about this issue?

1----------------2----------------3----------------4----------------5----------------6----------------7
Very Strongly No
Feelings

2. People should be allowed to have gay and/or lesbian relationships.

1----------------2----------------3----------------4----------------5----------------6----------------7
Strongly Agree Strongly
Disagree

How strongly do you personally feel about this issue?

1----------------2----------------3----------------4----------------5----------------6----------------7
Very Strongly No
Feelings

3. Women have the right to have an abortion.

1----------------2----------------3----------------4----------------5----------------6----------------7
Strongly Agree Strongly
Disagree

How strongly do you personally feel about this issue?

1----------------2----------------3----------------4----------------5----------------6----------------7
Very Strongly No
Feelings

4. People have a right to have a baby outside of marriage.

1----------------2----------------3----------------4----------------5----------------6----------------7
Strongly Agree Strongly
Disagree

How strongly do you personally feel about this issue?

1----------------2----------------3----------------4----------------5----------------6----------------7
Very Strongly No
Feelings

5. Sex between an unmarried man and unmarried woman is acceptable.

1----------------2----------------3----------------4----------------5----------------6----------------7
Strongly Agree Strongly
Disagree

How strongly do you personally feel about this issue?

1----------------2----------------3----------------4----------------5----------------6----------------7
Very Strongly No
Feelings

6. There is nothing wrong about buying and wearing clothing made of animal fur.

1----------------2----------------3----------------4----------------5----------------6----------------7
Strongly Agree Strongly
Disagree

How strongly do you personally feel about this issue?

1----------------2----------------3----------------4----------------5----------------6----------------7
Very Strongly No
Feelings

7. There is nothing wrong with conducting medical testing on animals.

1----------------2----------------3----------------4----------------5----------------6----------------7
Strongly Agree Strongly
Disagree

How strongly do you personally feel about this issue?

1----------------2----------------3----------------4----------------5----------------6----------------7

Very Strongly Feelings   No

8. People should be allowed to gamble.

1----------------2----------------3----------------4----------------5----------------6----------------7
Strongly Agree   Strongly Disagree

How strongly do you personally feel about this issue?

1----------------2----------------3----------------4----------------5----------------6----------------7
Very Strongly Feelings   No

9. There is nothing wrong about conducting medical research using stem cells obtained from human embryos.

1----------------2----------------3----------------4----------------5----------------6----------------7
Strongly Agree   Strongly Disagree

How strongly do you personally feel about this issue?

1----------------2----------------3----------------4----------------5----------------6----------------7
Very Strongly Feelings   No

10. There is nothing wrong about the cloning animals.

1----------------2----------------3----------------4----------------5----------------6----------------7
Strongly Agree   Strongly Disagree

How strongly do you personally feel about this issue?

1----------------2----------------3----------------4----------------5----------------6----------------7
Very Strongly Feelings   No

11. The death penalty should be legal in all states.

1----------------2----------------3----------------4----------------5----------------6----------------7
Strongly Agree   Strongly Disagree

How strongly do you personally feel about this issue?

1---------------2---------------3---------------4---------------5---------------6---------------7
Very Strongly Feelings | No

12. Divorce is acceptable.

1---------------2---------------3---------------4---------------5---------------6---------------7
Strongly Agree | Strongly Disagree

How strongly do you personally feel about this issue?

1---------------2---------------3---------------4---------------5---------------6---------------7
Very Strongly Feelings | No

13. Suicide is acceptable.

1---------------2---------------3---------------4---------------5---------------6---------------7
Strongly Agree | Strongly Disagree

How strongly do you personally feel about this issue?

1---------------2---------------3---------------4---------------5---------------6---------------7
Very Strongly Feelings | No

14. Cloning humans is acceptable.

1---------------2---------------3---------------4---------------5---------------6---------------7
Strongly Agree | Strongly Disagree

How strongly do you personally feel about this issue?

1---------------2---------------3---------------4---------------5---------------6---------------7
Very Strongly Feelings | No

15. One husband having more than one wife at the same time (Polygamy) is acceptable.

1----------------2----------------3----------------4----------------5----------------6----------------7
Strongly Agree Strongly
Disagree

How strongly do you personally feel about this issue?

1----------------2----------------3----------------4----------------5----------------6----------------7
Very Strongly No
Feelings

16. Married men and women having an affair is acceptable.

1----------------2----------------3----------------4----------------5----------------6----------------7
Strongly Agree Strongly
Disagree

How strongly do you personally feel about this issue?

1----------------2----------------3----------------4----------------5----------------6----------------7
Very Strongly No
Feelings

APPENDIX B

Demographics Questionnaire

Participant #:________________________

Today's Date:____/____/____

1. Age:______ 2. Gender: Male / Female

3. Education (circle one)
   a. Freshman
   a. Sophomore
   b. Junior
   c. Senior
   d. Other: _______________

4. Race (Circle all that apply)
   a- Black b. White c. Hispanic/Latino

   d- Asian American e- Native American/Alaskan Native

   f- Middle Eastern/Arabic g – Native Hawaiian or Pacific Islander

   h- Other : _______ i – unknown/decline to respond

5. Have you ever been diagnosed with a psychological condition, such as depression or an anxiety disorder? (Please circle one)
   Yes No

If yes, please list:____

6. Have you ever been diagnosed with a learning disability? (Please circle one) Yes No

If yes, please list:____

7. Is English your native language? (Please circle one) Yes No

If no, what is your native language? __________________________

8. Do you have any memory difficulties? (Please circle one) Yes No

If yes, please explain: ____