THE ROLE OF WORKING MEMORY CAPACITY AND COGNITIVE LOAD IN PRODUCING AND DETECTING DECEPTION

by

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ABSTRACT

The purpose of this study was to examine the effects of age, working memory capacity (WMC) and cognitive load on people's ability to tell and detect lies. The literature is inconsistent on what individual characteristics are critical to being a good liar. Zukerman, DePaulo, and Rosenthal (1981) suggested that lying is cognitively demanding. Therefore, WMC might provide an advantage for some when telling a convincing lie, such that higher WMC individuals can handle the high cognitive load associated with lying. I examined this across two experiments. I predicted that individuals with higher WMC would be able to better tell more convincing lies, because such individuals are better at suppressing prepotent, but goal irrelevant information, such as the truth. Additionally, higher WMC individuals are better equipped to focus and tune out distraction that accompanies a high cognitive load. I also predicted that younger individuals will have an easier time telling convincing lies than older adults. As we age, cognitive functioning, like WMC, declines, and with this decline, so does our ability to deceive others. In Experiment 1, young adult dyads took turns telling truths and lies, under high and low cognitive load. The detector tried to determine whether their partner was truthful or deceitful. In Experiment 2, younger and older adults told truths and lies into a camera and two young adult detectors tried to detect the truths and lies, at a later time. I found a positive relationship between WMC and telling lies such that higher WMC individuals had fewer of their lies detected when under high load. I also found that a higher WMC improved the ability to comply when asked to tell a truth or lie. I also found that when responding to questions, participants found it easier to comply when asked to lie or when under high cognitive load. In regard to age differences, older adults found it more difficult to tell lies than truths. Issues within deception could involve specific memory processes and require more research to understand what aspects of memory are involved in telling a convincing lie.

INTRODUCTION

Lying is a common occurrence. Feldman, Forrest, and Happ (2002) found that when participants are given a goal to appear likeable and competent, in a 10-minute conversation with a stranger, 60% of participants told at least one lie and generally averaged three lies. Such frequent deceit should make us expert liars and lie detectors, but such is not the case. Despite extensive research on the characteristics of convincing liars and accurate lie detection, there is no golden rule one can follow and become an expert liar or lie detector. The current paper will examine how individual and situational differences in cognitive ability relate to one's ability to tell and detect lies.

Lying Convincingly

Several theories are used to explain why some people are convincing liars. Zuckerman, DePaulo, and Rosenthal (1981) performed a meta-analysis using parameters that evaluated the types of thoughts, feelings, behavioral cues and psychological processes that would most likely occur when someone lies compared to someone telling the truth. Based on their analysis, Zuckerman et al. found that liars show greater differences in arousal than those telling the truth and these differences can be seen in increased pupil diameter, blinking and speech disturbances. The authors also suggested emotions, such as fear and guilt, are more often exhibited by those who lie, than truth tellers. Additionally, the authors suggested that the cognitive demand is far greater during lying. Lastly, the authors note that liars might be aware of some of these cues and will try to modify their behavior in order to appear as though they are telling the truth, but this behavior modification could backfire, causing them to seem more deceptive.

Recent deception research has examined a cognitive load component to lying (Vrij, 2008). It is suggested that there is a cognitive load associated with telling a convincing lie because there are several behaviors and cognitions that must be controlled in order to be convincing. For instance, instead of simply holding one story in memory, the truth, two stories are held in memory, the truth and the lie. Additionally, the liar must hold both of the stories separate to avoid the truth contaminating the lie. Still, the liar must make sure the details of the lie match peripheral details surrounding the story. Furthermore, one must also be aware of, and appropriately manage verbal and non-verbal cues that might suggest deceptive behavior. Therefore, poor management of behaviors and cognitions relevant to telling a convincing lie strains cognitive ability and reduces the amount of control a liar has when telling a lie. The result of such poor management and lack of control can increase the likelihood of the liar getting caught.

Buller and Burgoon's (1996) Interpersonal Deception Theory explains that lying face-to-face is not a unidirectional event, but instead involves both the sender and the receiver working in tandem. For instance, verbal or nonverbal feedback can indicate to the sender whether or not the receiver is accepting the lie. The sender can then modify his or her performance based on this feedback. Therefore, decoding cues from one's partner is an important skill when telling a lie. Moreover, liars need to quickly and seamlessly use this feedback to modify their approach within the conversation. Therefore, when speaking, the liar needs to speak smoothly and with eloquence, or else, it might become obvious that the liar is using the feedback in order to be more convincing. When people believe they are being lied to, they could potentially become skeptical and dissect the conversation, which can lead to better lie detection.

According to Impression Formation Theory (Asch, 1946; Vrij & Winkel, 1992; Vrij, Granhag, & Mann, 2010), people make impressions and judgments instantaneously and use them to form the base and rationale for other impressions and judgments. O'Sullivan (2003) found that when an observer sees someone as trustworthy or untrustworthy, this impression transcends across situations. Additionally, DePaulo, and Friedman (1998) describe spontaneous sending, or expressiveness, as how easily a sender provides a receiver with specific feelings without making it obvious the sender is trying to send them. Expressive senders generally tend to elicit a positive first impression, are well liked, attractive, exude credibility, and can simulate and express a feeling they do not currently have (DePaulo & Friedman, 1998). These people are generally considered good actors, which helps them tell convincing lies.

Persuasion Theory (Hovland, Janis, & Kelley, 1953; Vrij et al., 2010) suggests perceived likeability and credibility are two factors that influence the persuasiveness of a communicator (Brehm, Kassin, & Fein, 1999). Certain behavior styles like direct gaze, posture mirroring (Tickle-Degnen & Rosenthal, 1990), moderately fast speaking, and vocal variety (Buller & Aune, 1987) improve likability. Credibility is developed when there is no obvious gain from successful persuasion.

In summary, convincing liars need to effectively manage several thoughts and behaviors in order to convincingly tell a lie. Understanding the situation and using cues from the environment will help liars tell a convincing lie. Those who are able to handle the high load associated with lying, and can rapidly think and respond eloquently while creating a likeable and credible impression, can improve their chances of being convincing.

Lie Detection

While it is important to understand what characteristics are required to be a good liar, it is also important to understand how to detect such lies. Traditionally, procedures used to detect lies rely on arousal (Vrij, Fisher, Mann, & Leal, 2006). The assumption is that a liar's body will display signs of arousal due to a fear of being caught. A common technique in detecting lies through arousal is a polygraph test. If skin conductivity and heart rate are elevated above baseline during some questions and not during others, one can conclude that the subject lied during these responses. Research has consistently demonstrated that the polygraph test measures physiological reactions to stress, fear, guilt, excitement, or anxiety that an examinee would feel during a response to a question (Saxe, Dougherty, & Cross, 1985; Ben-Shakhar & Elaad, 2003). Ideally, however, heightened responses should only appear when the response is to something mischievous, like lying.

Davis (1961) explained several theories historically used to account for these physiological responses during a polygraph test. In the Conditioned Response Theory, critical questions, such as questions requiring a lie response, are considered conditioned stimuli and should evoke an emotion associated with the past event. They are considered conditioned stimuli because the emotion experienced during the event was so great, that the emotion becomes linked to it. Therefore, when a question is asked about the event, the same emotion should be experienced. As a result, the theory suggests that a change in physiological response should only occur when critical questions are asked about the past event, and not to neutral baseline questions. Davis also explains a Theory of Conflict, in which two incompatible reaction tendencies elicited at the same time will produce a larger physiological response than if the two reactions occur in isolation. Finally, Davis suggested the Threat of Punishment Principle, which describes the possibility that someone will produce a large physiological response because they anticipate serious consequences if caught.

Despite the consistent use of these theories to explain why changes in physiological responses occur, there are several assumptions within the theories that are sometimes violated that could allow liars to go undetected. For instance, if I apply the Threat of Punishment Principle (Davis, 1961) to a bank robber, it is possible that the robber might not fear the punishment which, according to the theory, would not change the robber's physiological response. This would suggest to some that arousal might not be the most reliable way to determine deceit and would require the development of new procedures. The US National Research Council addressed this issue and stated that arousal-based detection of deception is not an effective way to catch a liar (National Research Council, 2003). The council examined Davis' theories and several other aspects of the arousal-based detection of deception and came to the conclusion that someone who is telling the truth can present as a liar, especially if they are scared they will not be believed. Similarly, a liar might not necessarily display more signs of arousal, especially if their goal is to appear innocent. Ultimately, the council reasoned that the polygraph identifies changes in physiology, regardless of the cause. This denouncement of arousal-based lie detection led to a call for alternative methods.

In recent years, electroencephalogram (EEG) and eye tracking techniques have been used as potential alternatives to arousal-based techniques. In EEG, several studies examined the P300 waveform in deception using autobiographical information, well-rehearsed information, and/or information learned in an experiment as tests of guilt knowledge (for a review, see Rosenfeld, Hu, Labkovsky, Meixner, & Winograd, 2013). Rosenfeld found that autobiographical information has been reliably detected (85-95%; Rosenfeld, Soskins, Bosh, & Ryan, 2004) but incidental information rates, or known information that is not directly related to the current line of questioning, have varied (27-95%; Rosenfeld et al., 2004) using EEG detection. Supporting this data, using EEG, Rosenfeld, Biroschak, and Furedy (2006) found that the P300 amplitude was greater for highly meaningful information. In deception, this meant that those who were asked a question about an event they needed to lie about showed a larger P300 than those who were asked a question about an event that had no significant meaning to them. Additionally, Meixner and Rosenfeld (2011) had participants participate in a mock terrorist plot, a simulated real life event, as opposed to mock crimes or questions about autobiographical information. Detectors used the P300-based concealed information test to detect guilty individuals. This was done by examining the difference between P300 waveforms for probe questions, or crime related items, and control items, or items that are not relevant to the event in question. Detectors were able to detect all 12 guilty participants who had knowledge of the terrorist attack using the P300-based concealed information test. Detectors were also able to identify 20/30 crime-related details with no false positives. Advances in EEG-based deception detection have proven useful and more research is needed to ensure its reliability, but current findings suggest that EEG-based deception detection might be a promising mode of deception detection in the future.

There is also evidence that eye movements, pupil diameter and blink rate are viable alternatives in detecting lies, relative to physiological responses like heart and respiration rates (Marchak, Keil, McMillan, & Westphal, 2011). Marchak (2013) recently examined whether changes in eye blinks can be used to expose deception. He found that those whose intent was to be deceitful had lower blink counts, shorter blinks, and were more likely to suppress blinks than those who were truthful. Cook et al. (2012) also examined ocular-motor measures of reading to detect deception. They found that those participants who were guilty of stealing $20 had larger pupil diameters than those who were innocent. Additionally, guilty individuals fixated on words longer when reading than innocent people, but generally read faster than innocent people. Continued research and perhaps marriage with other known detection techniques would allow ocular-based techniques to become a new method for deception detection.

In sum, arousal was once the gold standard for physiological deception detection. However, it has fallen out of favor and calls for a new method of deception detection have been made. Recently, neuroscientific measures, such as using the P300 or pupil diameter, have been developed as possible alternatives to conventional arousal-based techniques.

How Successful Are We at Detecting Lies?

Most people do not have access to a polygraph machine in everyday situations and they cannot monitor symptoms of arousal without seeming invasive or extremely bizarre. Instead, they generally must rely on their intuition to detect lies. But research shows that most individuals are not good at catching liars. Zuckerman et al. (1981) postulated that emotional reactions, cognitive effort, and attempted behavioral control all play a role in the way someone lies, which in turn makes every lie slightly different and hard to detect. Kraut (1980) did a review of studies examining lie detection and found that, for all the studies he reviewed through 1980, the accuracy rate was 57%. Vrij (2008) conducted a later review and found that the accuracy rate dropped to 54.27%. Both of these rates are just above chance. Further, trained policemen, individuals who should presumably have skill in detecting deception, have the same rate as a layperson in detecting lies (DePaulo & Pfeifer, 1986; Garrido, Masip & Herrero, 2004; Vrij & Graham, 1997).

However, there are some groups who are better than chance at detecting lies. Ekman and O'Sullivan (1991) had secret service members, federal polygraphers, robbery investigators, judges, psychiatrists, those with a special interest in deception, and college students watch 10 videos. The videos consisted of people lying or telling the truth about their current feelings. Of the seven groups, only the secret service members were better than chance in detecting lies. Ekman, O'Sullivan, and Frank (1999) conducted a similar study with seven groups: federal officers, sheriffs, federal judges, mixed-law enforcement officers, deception interested clinical psychologists, regular clinical psychologists, and academic psychologists. These participants watched videos of people who were lying or telling the truth about their opinions. They found that federal officers, sheriffs and deception-interested clinical psychologists were better than chance, and better than the other 4 groups, at detecting lies. These studies suggest that there are certain groups of people who are better at detecting lies and that good lie detection is not specific to law-enforcement groups, even though they might have special lie detection training.

Recently, there has been interest in a wizards' approach. This approach examines individuals who are deception "geniuses" such that they are able to detect deception at almost perfect rates. O'Sullivan and Ekman (2004) identified 29 "expert" lie detectors from 12,000 participants. These experts were able to correctly detect at least 9 out of 10 lies from a set of videos. Gary Bond (2008) gave a similar test but used 112 law enforcement officers and 122 undergraduates. He found 11 participants, all law enforcement officers, that were at least 80% accurate when watching 32 sets of videos where felons told truths or lies. A lack-of-evidence perspective has emerged arguing that these people obtained these scores by random chance. However, Blair, Levine, and Vasquez (2015) found that when participants were exposed to a somewhat regular environment, allowed practice at making deception judgments, and were given accurate feedback, participants can perform at an "expert" level, but only in the particular scenario, meaning the findings are not generalizable. Nonetheless, this does suggest that it is possible to develop deception detection expertise in the "real" world, if one practices for specific scenarios.

Recently, Vrij (2008) developed a new approach in which additional cognitive load demands are introduced during interviews. The premise for this approach is that lying is more cognitively demanding than telling the truth, so when someone is placed under cognitive load and then must lie, there will be a difference between truth telling and lying behaviors, such that stuttering, slower response times, reduced movements, inconsistencies, etc. will increase. These increased behaviors should ultimately increase the rate in which lies are detected. There are several studies examining the cognitive load approach. For example, Vrij et al. (2008) developed the reverse order technique in which participants must tell the story in reverse order, adding an additional cognitive load. Hartwig, Granhag, Strömwall, and Vrij (2005) used a strategic use of evidence approach where interviewers reveal evidence towards the end of questioning instead of at the beginning. This would force a suspect to manage information in order to avoid saying something that is inconsistent with the evidence. Walczyk, Mahoney, Doverspike, and Griffith-Ross (2009) had people respond to close ended questions under time pressure. These studies all required suspects to tell a story under a cognitive load, which resulted in noticeable behavioral changes.

Blandon-Gitlin, Fenn, Masip, and Yoo (2014) tried to describe what mechanism would account for the behavioral changes during lying. For instance, the authors suggest that, in reverse order recall, it might be easier for an individual to recall an event if they remember it in forward order then retell the event in reverse order. However, a liar can find this detrimental because the lie will be qualitatively different than the truth, so to imagine the lie will take more cognitive effort. Previous research is consistent with this account, showing that imagination indeed requires more cognitive effort than retrieving an experienced event (Addis & Schacter, 2012). Blandon-Gitlin et al. also suggest that liars might use strategies that are simple and require few resources. Hoffmann, van

Helversen, and Rieskamp (2013) explain that task demands can dictate the strategy used in a given situation and that high-demand situations, situations that require someone to complete multiple tasks simultaneously, such as lying, cause people to use strategies that require less working memory capacity. But, using this strategy might not be effective. When lying, it might not be to one's advantage to use a simple strategy because it might increase the chances of slipping up or getting caught.

In sum, the literature suggests most people are not good lie detectors, but some individuals are better than chance. The cognitive load approach provides an opportunity for detectors to improve their chances of detecting lies through discriminable behavior changes in the liar. However, research is not clear on what mechanism accounts for the behavior changes elicited when lying under cognitive load.

Working Memory Capacity

As discussed above, the goal of the cognitive load approach is to exceed the working memory capacity of the individual during questioning. Working memory capacity is an individual difference construct that can measure how much cognitive load someone can handle before their capacity is exceeded. Working Memory Capacity (WMC), as described by Engle (2002), involves short term memory and attentional control, such that WMC is not just how much information one can hold in short term memory but also how well someone can focus on this information while simultaneously tuning out distraction.

Complex span tasks are often used to measure WMC. There are several variants including the Operation Span Task (OSPAN; Turner & Engle, 1989) and the Reading

Span Task (RSPAN; Daneman & Carpenter, 1980) among others. Briefly, participants are asked to remember a string of 2 to 7 letters, but between each letter is either a math equation (OSPAN) or a sentence (RSPAN). The goal is to determine if the provided answer to the math equation is correct or not or if the sentence read makes sense. After responding to between 2-7 of these equations or sentences, the participant must then recall the letter string in order. These tasks were created based on Baddeley and Hitch's (1974) concept of working memory, which urged the importance of a functional system that allowed an individual to keep and maintain task-relevant information while performing complex tasks. Therefore, these WMC tasks examine how much task-relevant information can be stored while completing another task.

Previous research suggests telling a lie is cognitively demanding (Zuckerman et al., 1981; Vrij et al., 2006), which likely makes the ability to handle a high cognitive load an important characteristic for telling a lie. For instance, one must keep track of what is said and ensure the truth and the lie remain separate. This could lead to slower response times (Walczyk, Roper, Seemann, & Humphrey, 2003) and a decrease in hand, foot and leg movements (Sporer & Schwandt, 2007). But, good liars are not affected by cognitive load (Vrij et al., 2006; Vrij et al., 2010). Therefore, there might be a link between WMC and telling a lie such that individuals with higher WMC might be better able to keep a lie and a truth separate, in addition to monitoring themselves for other cognitive and behavioral cues, than those with low WMC.

There are likely four abilities common in individuals with high WMC that could allow them to convincingly tell a lie, regardless of the current cognitive load. First, individuals with high WMC can inhibit inappropriate, yet dominate, responses. In order for the lie to be convincing, someone must inhibit the dominate truth response and instead respond with a lie. Kane, Bleckley, Conway, and Engle (2001) showed that low-WMC individuals were less able to block reflexive eye movements to abrupt-onset cues that conflict with task goals, and these difficulties were not limited to novel situations that involve minimal practice. Therefore, when lying, low WMC individuals might have difficulty suppressing the truth, causing them to get caught. Still, research demonstrates that in conflict tasks (Kane et al., 2001; Kane & Engle, 2003), low WMC individuals are slower and less accurate in responding when conflict arises. This suggests, when telling a lie, higher WMC individuals might inhibit the truth more quickly, further enabling them to maintain a truthful appearance.

Second, high WMC individuals have superior conflict monitoring (Botvinick, Braver, Barch, Carter, & Cohen, 2001). This allows an individual to monitor their performance and make corrections when a conflict arises. When lying, one must monitor the story they are telling to ensure what is said supports their lie. If potential conflict is detected early, high WMC individuals can alter their response before they provide inconsistent information. Research by Weldon, Mushlin, Kim, and Sohn (2013) suggests increased WMC indeed relates to increased ability to successfully monitor conflict, appropriate to contextual demands. Miller, Watson, and Strayer, (2012) support this by examining the Anterior Cingulate Cortex (ACC), the brain's conflict monitoring center, and finding that those individuals with higher WMC showed a larger Error Related Negativity, an Event Related Potential (ERP) thought to arise when the ACC detects conflict. Additionally, higher WMC individuals also showed larger posterror positivity, an ERP associated with the ability to update cognitive strategies. This suggests high

WMC individuals might have a better attentional control network which allows them to better monitor their performance for interference and refresh a task goal if interference is detected. When telling a lie, a high WMC individual can monitor the details of the lie for conflict and recover better than a low WMC individual.

A third element to deception that high WMC individuals might have success with is maintaining context and task goals. Often, a lie occurs over multiple encounters or must be sustained during a conversation. Therefore, it is important to maintain as much information concerning the lie as possible and ensure other details are consistent. Otherwise, it could be easy for someone else to identify conflicting facts within one's story. Research suggests that high WMC individuals might be more capable of maintaining the task goal and/or task relevant information in order to successfully complete the task (Hutchison, 2011; Kane & Engle, 2003). Hutchison (2011) examined performance on a modified Stroop Task in which lists either frequently or seldom contained congruent or incongruent colors. In order to perform well on this task when incongruent colors are rare, one must maintain the task goal of color naming. Otherwise, the individual might rely on habit and read the word during a rare incongruent trial. Hutchison (2011; also see Kane & Engle, 2003) found that those with higher WMC individuals were better able to keep the task goal and avoid relying on habit, which reduced the number of errors and increased overall performance. A similar process holds for lying, such that forgetting the goal of 'keep the lie constant to be convincing' can increase the possibility that one might slip up and accidently insert truthful details, increasing the chances of being caught.

Lastly, a fourth element that could be key to deception is an ability to multitask. One must balance several aspects of deception in order to convincingly tell a lie. This includes holding the truth and lie in memory, keeping them separate, using the cues from the receiver as a baseline for your story, and suppressing any behavior that could signal lying. Recent research suggests that those with a high WMC might be better able to complete tasks simultaneously than those with low WMC (Colom, Martinez-Molina, Shih, & Santacreu, 2010). Hambrick, Oswald, Darowski, Rench, and Brou (2010) found that WMC was a better predictor of multitasking than processing speed. Interestingly, WMC also predicted use of an effective strategy, which suggests individual differences in WMC partially reflect one's ability to find and implement effective strategies for cognitive tasks. When relating these results to deception, it is possible that those who have high WMC might not only be better multitaskers but they might also find the best strategy for their situation and implement it appropriately to tell a convincing lie.

Taken together, high WMC individuals will delegate the necessary amount of resources across all components of a task, such as lying, including keeping the truth and lie separate in memory, successfully monitoring the story for errors, and monitoring and regulating any behavioral cues that could hinder them from telling a convincing lie. Furthermore, if an error should occur, higher WMC individuals will readily regain the task goal.

Deception and Older Adults

All the studies cited above excluded older adults. However, older adults are certainly capable of lying and are often in positions in which they are lied to. Research suggests that older adults are not very good at either lying or detecting lies. One of the first studies conducted using older adults used a non-interactive paradigm in which older adults judged videotapes of younger adults' truthful or deceptive reactions to sweet and bitter drinks (Parham, Feldman, Oster, & Popoola, 1981). The authors found that older adults were able to identify the deceptive behavior of young adult males, but were not as accurate for the deceptive behaviors of young adult females. Bond, Thompson, and Malloy (2005) found that older adults were better than young adults at detecting lies from younger adults, but this result was driven by the performance of older adult females. Recently, Ruffman, Murray, Halberstadt, and Vater (2012) examined age-related differences in deception using a mixed-age group approach. Younger and older adults were asked to watch videos of younger and older adults being truthful or deceptive regarding opinions on various issues. Ruffman et al. found that participants were able to detect lies well within their age group, but older adults had difficulty detecting lies from younger adults. Younger adults were still able to detect older adult lies well.

Little research has looked at age differences in WMC and deception, but a large literature on cognitive function in healthy aging suggests older adults experience declines in episodic memory, inhibition, attention, executive function, and, most importantly for the purpose of this paper, working memory (Hedden & Gabrieli, 2004). Mattay et al. (2006) suggest that older adults have cognitive limitations because there are widespread neural and metabolic decays that result in cellular, molecular and structural changes as they age. Additionally, in old age, executive functioning declines, which could lead to similar deficits in deception to that seen among low WMC individuals. Specifically, because of declines in executive function, older adults might not be successful at telling convincing lies because of deficits in the four potential WMC-related contributions to deception: Inhibiting inappropriate, yet dominate responses, conflict monitoring, maintaining context and task goals and multitasking.

Several studies suggest that older adults see performance decrements in the anti-saccade task, a task often used to examine inhibition (Butler, Zacks, & Henderson, 1999; Olincy, Ross, Youngd, & Freedman, 1997). Butler and Zacks (2006) further investigated inhibition in older adults by examining older adult's ability to control prepotent responses. However, instead of only using a traditional anti-saccade paradigm that requires participants to look in the opposite direction of a peripheral stimulus in order to name a target, this paradigm also used a modified anti-saccade task in which a central arrow signified where the target would be. In an anti-saccade trial, the arrow would point in the opposite direction of the target, in a pro-saccade trial, the arrow would point in the same direction as the target. Older adults saw greater deficits in the peripheral cue condition than in the central cue condition. This suggests an inhibitory deficit in aging, because deficits were experienced when the inhibitory demands were high, but not when they were low. Because of this inhibitory deficit, when lying, older adults should have difficulties inhibiting a dominate truthful response, especially when the inhibitory demands are high.

Recent research also suggests that older adults have deficient conflict monitoring. West (2004) examined the modulation of conflict monitoring specific waveforms, such as the ERN, and found older adults experience less modulation. This suggests that areas in the brain associated with conflict monitoring, like the Anterior Cingulate Cortex, are less responsive to conflict. Czernochowski (2014) further supports this and suggests older adults must recruit more neural resources in order to successfully monitor for conflict, which is cognitively demanding and reduces the speed by which conflict is monitored. When lying, older adults should be slow to react or miss conflict entirely, potentially allowing their lie to be detected.

Older adults also experience deficits in maintaining task goals. Comalli, Wapner, and Werner (1962) were among the first to demonstrate that the Stroop Effect is constant in middle age, but increases in older adults. West and Baylis (1998) demonstrated that this increase in the Stroop effect occurred when the demand for inhibition was high (i.e. mostly incongruent trials), versus when there was a low need for inhibition (i.e. mostly congruent trials). Paxton, Barch, Racine, and Braver (2008) suggest that, due to decreased activation in the pre-frontal cortex, a brain region associated with regulating access to goal representations, older adults see declines in goal maintenance. When lying, this would suggest that older adults should experience difficulties maintaining a task goal of maintaining a convincing lie, leading to potential "slips" in which they reveal truthful information that contradicts their lie.

Lastly, research demonstrates that working memory performance decreases when older adults are distracted and even larger deficits are experienced when multitasking (Clapp & Gazzaley, 2012). Neuroimaging further demonstrates that older adults experience performance decreases because they have difficulty recovering from interruption, such that when a task requires someone to reallocate attentional resources to perform a secondary task, older adults have a hard time re-engaging in the original task (Clapp, Rubens, Sabharwal, Gazzaley, & Raichle, 2011). As discussed previously, lying creates a multitasking problem and older adults should experience difficulties coordinating all the behaviors necessary to be convincing.

The Current Study

In the current studies, I examined the relation between WMC and the production and detection of lies under high and low cognitive load across age groups. Based on the review of the literature, I predict that individuals with high WMC would tell more convincing lies because they are better at inhibiting the truth. Additionally, they should be better able to detect lies, because they will presumably be able to focus more on potential lying behavior. Furthermore, high WMC individuals should be relatively unimpaired when lying during a high cognitive load, but lower WMC individuals should experience more difficulties when lying under high cognitive load. I also expect to see overall age-related differences in ability to tell a lie, such that younger adults will outperform older adults in the production of convincing lies.

EXPERIEMNT 1

Methods

Participants

One hundred and thirty-eight Montana State University students participated in the study for partial course credit in an Introduction to Psychology course. Data from 36 participants were not analyzed due to either computer error, experimenter error, or inability to comply with instruction. Some of the excluded data included four participants who made more than 20% math errors on the abbreviated OSPAN task (Foster et al., 2015). No one was eliminated for making more than 20% errors on the abbreviated Reading Span task (Oswald, McAbee, Redick, & Hambrick, 2015). Once I found all the participants eligible for data analysis, I took the first 32 dyads with complete data[1]. Thus, data from 64 participants were analyzed. Care was taken to ensure participants did not know each other beforehand to prevent participants from using prior knowledge to gain an advantage during the task. Participants were asked if they knew each other prior to participating in the experiment and once more during an exit survey.

Design

The design was a 2 x 2 x 2 mixed model with Load (high and low), Response Type (truth and lie) and Role (speaker and detector) measured within groups and WMC measured continuously between groups.

[1] While collecting data, I initially wanted to eliminate those individuals who were not able to comply with instruction at least 80% of the time. Upon further consideration, the decision was made to include these individuals to examine whether WMC related to simply being able to comply with the required response.

Procedure

When dyads arrived, they were first given a consent form and, following its completion, were given 64 questions to answer truthfully. The experimenter immediately engaged participants when they entered the lab so there was no opportunity for participants to talk to each other prior to the experiment.

After truthfully answering the initial 64 questions, participants were presented with the Foster et al. (2015) shortened OSPAN task. The shortened OSPAN allows researchers to choose how many shortened blocks of the task participants need to complete. In the current study, participants completed all three blocks. Each block presented participants with a simple math problem (e.g. 4 x 5 + 2 = 22) and instructed them to respond “yes” or “no” via mouse press, depending on whether or not the answer to the question was correct. Following the math problem, a single letter (e.g. L) was presented for participants to retain in memory. After viewing between 2 to 7 sets of math/word pairs, participants were instructed to recall the letters in the correct order. Their OSPAN score was determined by the number of the correctly recalled letters for sets in which all letters were recalled in the correct order. Participants were then presented with the Oswald et al. (2015) shortened RSPAN task. This task followed the same procedure as the OSPAN task, except instead of solving math equations, participants were presented with a sentence and instructed to respond “yes” or “no” by mouse press indicating whether or not the sentence made sense.

Upon completion of the span tasks, participants were given a packet with instructions for the memory load, the speaker task, and the detector task. Figure 1 shows the first block of trials for each participant. The participant randomly assigned to be the speaker was first shown a 4x4 matrix with four dots for four seconds and asked to remember the location of the dots for later recall. The dots were either in a straight line (low load, see Packet A in Figure 1) or scattered throughout the matrix (high load, see Packet B in Figure 1). Then the experimenter read 8 questions to which the speaker was asked to answer truthfully or deceitfully. The speakers answered the 8 questions based on a random order of four truths and four lies provided to them in their packet. The speaker's partner, initially assigned to be the detector, tried to determine if the speaker was lying to them or not and recorded their response in their packet. The experimenter wrote down the responses from the speaker to ensure the speaker complied with the instruction to tell a truth or a lie. Once the questions were answered, the speaker then filled in the matrix they saw at the beginning of the trial. Once completed, roles were reversed for the next block of 8 questions. The goal for the speaker was to be convincing in all responses and the goal for the detector was to correctly discern whether the speaker was lying or telling the truth for each response. This process repeated three more times. At the end of the experiment, participants were asked to complete an exit survey. The survey contained questions that asked about participant performance on the task, their partner's performance on the task, and whether or not they knew their partner prior to the experiment.

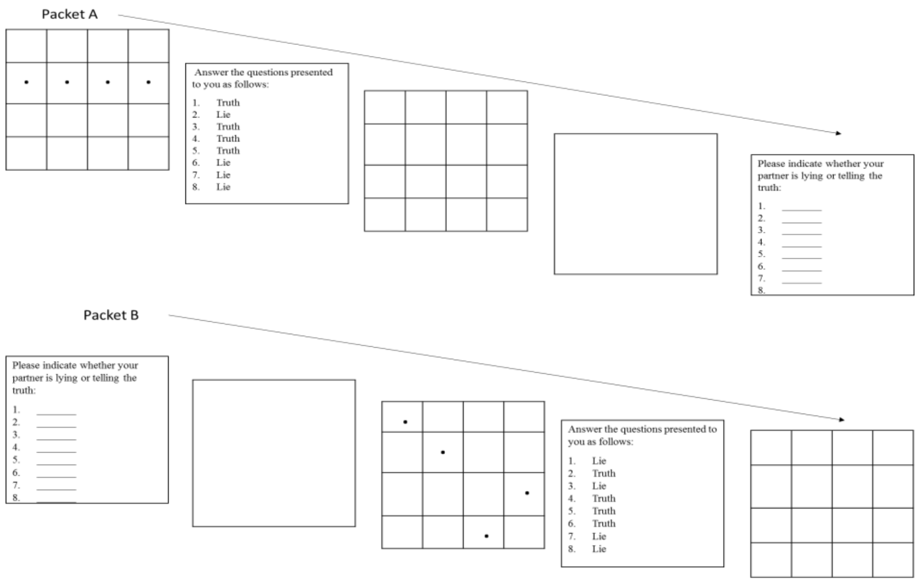

Figure 1. Sample trial under low memory load (top) and high memory load (bottom).

<u>Materials</u>

<u>Questionnaire</u>. Participants answered 64 questions requiring one-word or two-word truthful answers prior to the experiment. Questions included “What was the name of the first elementary school you attended?” or “In what city or town does your nearest sibling live?” Questions with 1-2 word answers were used because they allow for intrusion of a correct response during later lies, control for complexity of answer, and allowed us to examine response latency in future studies.

<u>Packet</u>. Participants were given packets in which the procedure was clearly explained. The packets were 20 pages total. The first two pages contained the 64 questions that were answered initially. If the participant received Packet A, the first page of their packet was a 4x4 matrix which contained four solid dots. A high load matrix contained four dots randomly dispersed within the matrix and a low load matrix would have the four dots in a straight vertical or horizontal line (See Figure 1). On the next

page, the participant then saw the words "Lie" and "Truth" four times each in a random order. This is how the participant knew how to respond to each of the experimenter's questions. The next page contained a blank 4x4 matrix in which the participant filled in with the matrix retrieved from memory during that block of questions. The last page the participant saw during a trial was a sheet with 8 blank lines on it. The participant used this sheet to write down whether their partner was lying or telling the truth.

If the participant received packet B, the participant detected lies first. In this case, the first page the participant saw was a sheet with 8 blank lines on it. The participant was to use this sheet to write down whether their partner was lying or telling the truth. The participant then saw the 4x4 matrix and was asked to remember it for later recall. On the next page, the participant saw the words "Lie" and "Truth" in random order indicating how to respond to the experimenter's questions. The last page contained a blank matrix the participant filled in based on memory. This sequence occurred four times.

Exit Survey.[2] The last page of the packet contained an exit survey which contained the questions "Did you know the other participant prior to today?" "What factors did you use to determine if the participant was lying?" and "Do you believe you are a good liar? Why?" These questions were used to ensure participants did not know each other beforehand and also to serve as a qualitative report on how well participants believe they lie and catch lies.

[2] Exit survey data was collected but not used in analysis. I do intend to examine this data to understand the relationships between perceived and actual performance and if there are any relationships between WMC and strategies used to tell or detect lies.

Results

Data Scoring

OSPAN and RSPAN scores were first transformed to Z-Scores. The WMC composite score was created by averaging standardized OSPAN and RSPAN scores. This composite was then used in the subsequent analyses.

I first ensured that the speaker complied with the instructions regarding when to tell a truth or a lie. To do this, I compared participants' initial answers with the responses they gave during the experiment. If the speaker told the same answer during the experiment, the response was scored as a truth. If the answers were different, then the response was scored as a lie. I marked the response as incorrect (M=3.86, SD=2.63) if their response (lie or truth) did not match the instructions. Additionally, I separately coded responses of "I Don't Know" (M=.25, SD=.62) during the speaking task as an indicator that the participant had difficulty quickly generating a lie or difficulty remembering a truth.

The detectors' coding of the speakers' responses were also examined. Figure 2 demonstrates the four potential outcomes between the actual response and detector's response. A hit occurred when the detector correctly detected the speaker's lie. A Miss occurred when the detector detected a truth when the speaker told a lie. A false alarm occurred when a detector detected a lie when the speaker told a truth. A correct rejection occurred when the detector detected a truth when the speaker told the truth.

		Actual Response	
		Lie	Truth
Detector's Response	Lie	Hit (Lie was detected)	False Alarm (A truth was perceived as a lie)
	Truth	Miss (Lie was believed)	Correct rejection (A truth was considered a truth)

Figure 2. Four outcomes between the actual response and detector's response.

Signal detection theory (Macmillan & Creelman, 2004; Nevin, 1969) allowed me to calculate d', or discriminability, and C, criterion. Discriminability is a measure of how well individuals can distinguish between the presence and absence of an event (e.g., a lie) independent from their overall bias for responding present or absent. For instance, in the current paradigm, a detector could classify every response is a lie, which would give the illusion of perfect detection if one only examined hit rates without considering false alarm. By calculating d', I can control for this response bias, that is, control for a detector's bias to classify responses as a lie or truth. To calculate d', I found the difference between a standardized hit score and a standardized false alarm score and divide this value by the square root of 2:

$$d' = [\, z(Hit) - z(FA) \,] / \sqrt{2}$$

d' ranges from 0, or no discriminability, to infinity, or perfect discriminability. This analysis used a correction developed by Macmillian and Creelman (2004, pg. 21) in which cases that equal 0 or 1 are changed to be 0.005 and .995, respectively.

Criterion examines the detector's response. To calculate C, I negated the sum of a standardized hit score and a standardized false alarm score and divided this by the square root of 2:

$$C = -[\, z(Hit)+z(FA)\,]/\sqrt{2}$$

Memory Task. As a manipulation check, I examined the effectiveness of the low vs. high load task. This was accomplished by examining significant differences between the number of correctly localized dots between high and low load conditions. A paired samples t-test revealed that participants did successfully remember the location of more dots in the easy matrix (*M*=7.82) compared to the hard matrix (*M*=6.67), $t(131)=7.615$, $p<.001$.[3]

Compliance

All significant effects are associated with a two-tailed $p<.05$. I first examined the participants' ability to comply with instructions using an ANCOVA with Load (High vs. Low) and Response Type (Lie vs. True) as within subject factors and Speaker WMC as a continuous covariate. There were significant main effects of Speaker WMC [$F(1,62)=5.080$, $MSE=8.145$, $\eta_p^2=.076$] and Response Type [$F(1,62)=26.804$, $MSE=42.216$, $\eta_p^2=.302$] on compliance, such that individuals were more likely to comply when they had higher WMC or when telling a lie (see Figure 3). The interaction between Speaker WMC and Response Type did not approach significance, $F(1,62)=1.926$, $MSE=3.034$, $p=.170$, $\eta_p^2=.030$.

[3] Note that these means are based on the combined performance on two matrices, for each load. Therefore, the means are based on a possible eight dots, not only four, as seen in Figure 1.

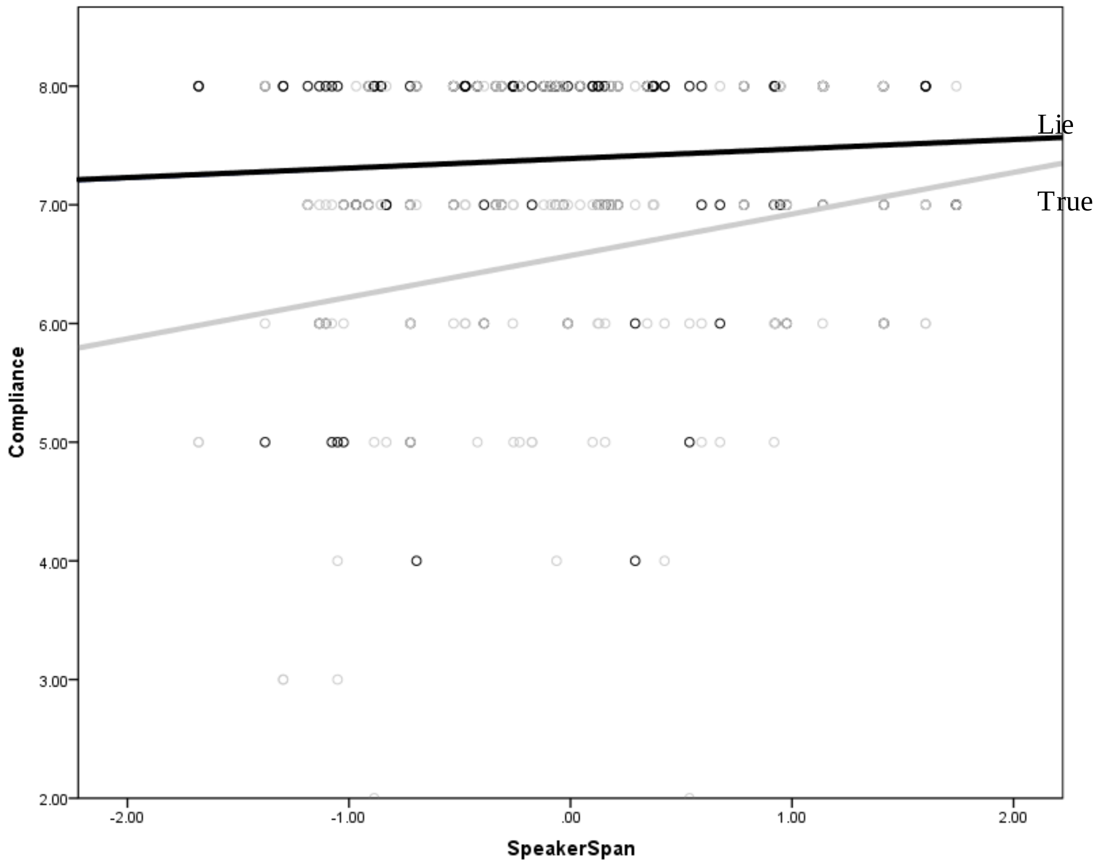

Figure 3. The effect of Speaker WMC and Response Type on compliance.

<u>Lie Detection Performance</u>

I next examined the effects of cognitive load and speaker and detector WMC in lie detection using a repeated measures ANOVA with d' under high and low load as a within subjects' factor and speaker WMC composite score, detector WMC composite score and the speaker x detector WMC composite score interaction term as covariates. The WMC composite score was created by taking the average of the RSPAN and the OSPAN score. I found a significant interaction between load and the Speaker x Detector WMC composite score interaction term, $F(1,60)=4.821$, $MSE=2.495$, $\eta_p^2=.074$. To better understand this 3-way interaction, I used linear regression to examine performance separately under high and low load using Speaker WMC, Detector WMC and the Speaker x Detector interaction term as independent variables. The Speaker x Detector WMC interaction was significant under low load, $\beta = -.303$, $t(63) = -2.436$, p=.018, but not under high load $\beta = .077$, $t(63) = .596$, p=.553. The bottom graph of Figure 4, shows speakers with higher WMC under low load were detected less often when speaking to high and medium WMC detectors, but were detected more often when speaking to low WMC detectors. To demonstrate this in Figure 4, Detector WMC was split into tertiles.

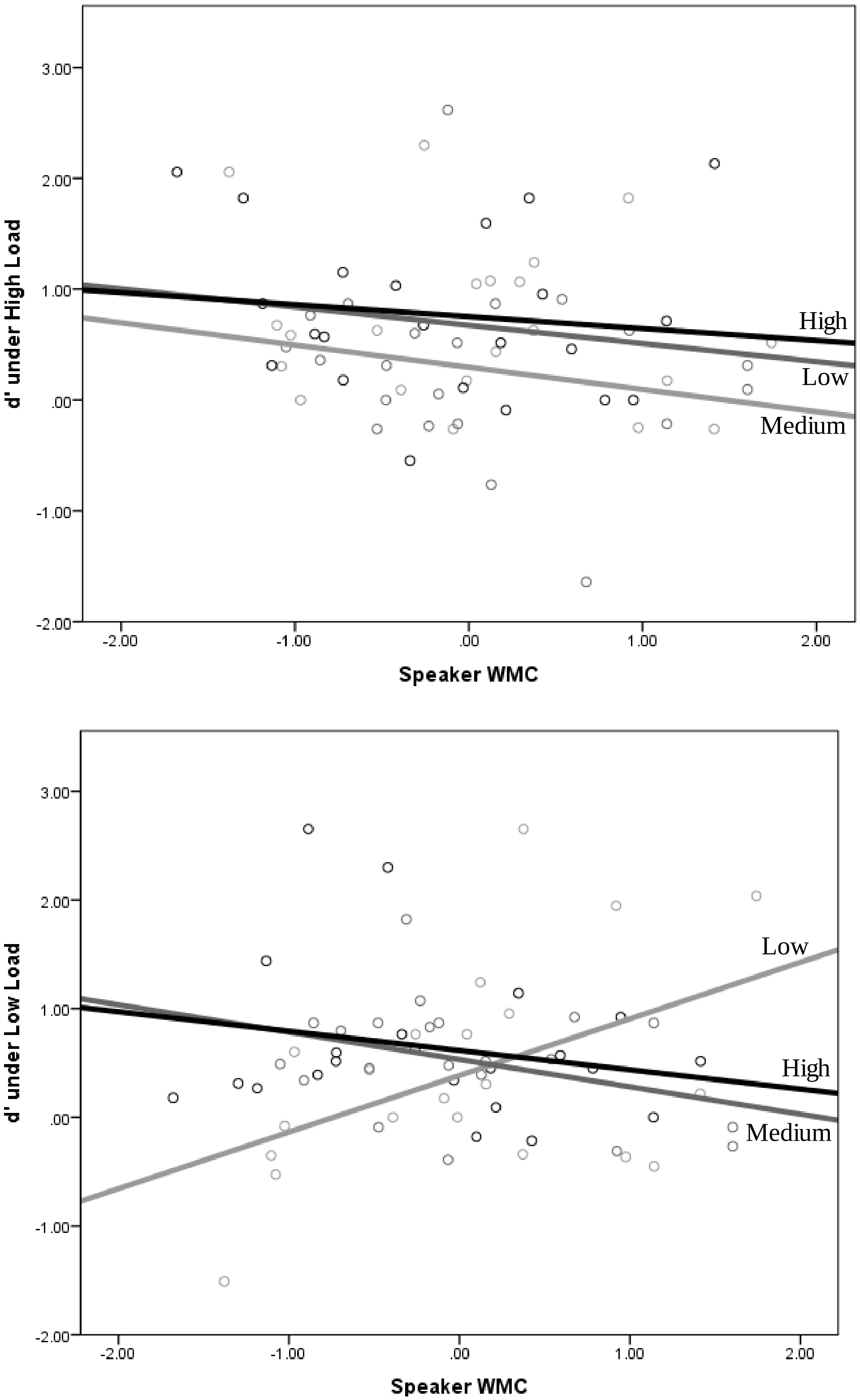

Figure 4. Speaker's ability to tell lies under high (top) and low (bottom) load by detector's WMC.

I conducted the same analysis, but used OSPAN and RSPAN scores individually, instead of the WMC composite score. I did not find any significant main effects or interactions for either RSPAN (Fs< 2.5, ps>.115, $\eta_p{}^2$<.041) or OSPAN (Fs<3.3, ps>.073, $\eta_p{}^2$<.053). However, I did find a significant negative correlation, r=-.261, p<.05 between speaker's RSPAN score and d' under high load, but not under low load, r=.025, p>.05 (See Table 1, top row). This suggests increased speaker WMC is associated with a decrease in detectability. Therefore, I then conducted a repeated measures ANOVA with d' under high and low load as a within subjects' factor and Speaker's RSPAN as a covariate. I found a marginal Load x RSPAN interaction [F(1, 62)= 2.922, MSE=1.556, $\eta_p{}^2$=.045]. As suggested by the correlations in Table 1, higher WMC individuals told more convincing lies than lower WMC individuals under high load, but not under low load.

Table 1.
Correlations Among Speaker RSPAN Scores and Lie Discriminability in High and Low Load Conditions

Experiment	Variable	Speaker RSPAN	Speaker OSPAN	High Load d'	Low Load d'
Dyad	Speaker RSPAN	1	.388**	-.261*	.025
Single YA	Speaker RSPAN	1	.594**	-.186	-.106
Single OA	Speaker RSPAN	1	.559**	-.070	.011
Combined YA	Speaker RSPAN	1	.480**	-.220*	-.016

Note. **Correlation is significant at the .01 Level (2-tailed).
* Correlation is significant at the .05 Level (2-tailed).

Additionally, I examined the relationship between detection and dot memory. Memory for low load dot matrices did not correlate with detection under high (r=.021, *p*=.871) or low load (*r*=.053, *p*=.679). Similarly, memory for high load dot matrices did not correlate with detection under high (*r*=.048, *p*=.708) or low load (*r*=-.010, *p*=.937).

Lastly, I averaged the hit rate and correct rejection rate to create overall detectability under high and low load. Overall detectability was 62.4% under high load and 61.6% under low load. One-sample t-tests show that participants were able to detect lies significantly greater than chance in both load conditions ($ts>2$, $ps<0.05$). Similarly, one sample t-tests conducted on d' show participants were able to discriminate lies from truth under both high $t(63)=5.942$, $M=57.82$ and low load $t(63)=5.547$, $M=.5243$.

Discussion

In Experiment 1, I examined the relationship between deception, cognitive load and WMC. Specifically, I tested whether high WMC individuals are better at lying, even under a high cognitive load. I found that WMC and whether someone needed to respond truthfully or deceitfully influenced how well someone could comply with directions. Specifically, higher WMC individuals had an easier time telling a truth or lie when asked, regardless of load or response type. Furthermore, I found that regardless of WMC and load, it was easier for individuals to comply with the task if they needed to tell a lie. This could be the result of poor memory. When telling the truth, the participant must remember what they had originally written in order to comply with the task. If under load, it is possible that remembering the original response was a more difficult task because there was only one right answer, opposed to an infinite number of possibilities when telling a lie. Additionally, changing one's mind regarding the answer to a question gets scored as non-compliance and further disrupts performance.

I also examined how WMC influences someone's ability to lie. I found that speaker and detector WMC worked in tandem in order to produce a convincing lie. This might be due to the speaker and detector trying to understand each other and influence the other to lie or detect in a specific way in order to gain an advantage. Buller and Burgoon (1996) suggested that lying is not unidirectional and I might have captured this in effect here. Interestingly, under low load, higher WMC speakers had their lies detected less often when speaking to a medium or high WMC detector than when speaking to a low WMC detector. I should caution however, that these results could be spurious in nature because there was no overall effect of WMC. However, when I examined the relationship between the speaker's RSPAN score and detectability, I found that high RSPAN scores were indeed related to less detectability. This suggests that WMC could play a role in deception, such that higher WMC individuals can handle an increased cognitive load when lying, providing an advantage in a situation that requires deceit. It is also worth noting that RSPAN examines WMC within the verbal domain. Because lying is a verbal task, it is possible that RSPAN is more sensitive to lying ability because they both exist in the same domain.

One potential issue with Experiment 1 was the variability in WMC within a dyad, such that a high span could be lying to a low span and vice-versa. Figure 4 demonstrates how volatile this variability can be. This could be problematic because the speaker's ability to convincingly lie might depend on the variable detector WMC. Therefore, keeping the detector constant should eliminate noise due to the detector's WMC. As in Experiment 1, I expect to find that high WMC individuals will tell more convincing lies.

Additionally, there is little research on the relationship between deception, cognitive load and WMC in older adults. As mentioned above, as we age, executive functioning declines. This might, in turn, make older adults more susceptible to being detected when trying to lie. Therefore, I expect to see overall age-related differences in ability to tell a lie, such that younger adults will tell more convincing lies than older adults.

EXPERIMENT 2

Purpose

The purpose of Experiment 2 was twofold. First, I wanted to examine the effect of load and WMC on one's ability to tell a lie when the detector is held constant. Second, I wanted to observe differences in the ability to tell lies across age groups.

General Overview

In Experiment 2, participants responded to a camera, rather than to a partner. Later, two young adult detectors attempted to discern lies from the truth. Participants included both older and younger adults.

Methods

Participants

Fifty-nine younger adults from Montana State University and thirty-five older adults from the surrounding community participated in the study for partial course credit in an Introduction to Psychology course or for a $15 Target Gift Card. Data from two younger adults and three older adult participants were not analyzed due to experimenter error or inability to comply with instruction.

Design

The design was a 2 x 2 x 2 mixed model with Load (high and low) and Response Type (truth and lie) measured within groups, Age as a between-groups factor and WMC was measured continuously between groups.

Procedure

The procedure for Experiment 2 was the same as Experiment 1 except for two changes. Instead of speaking to a partner, the participant spoke to a camera. A Sony digital camera was used to capture participant responses. All files were stored on a password protected computer. Additionally, because the detector was replaced with a camera, participants did not switch roles, which altered the packet slightly such that a speaker did not have to detect.

As in Experiment 1, each participant was first given a consent form and, following its completion, was given the 64-questions to answer truthfully. After truthfully answering the initial 64 questions, participants completed both the OSPAN and RSPAN task. Upon completion of the span tasks, older adults only completed the Folstein Mini Mental State Exam (MMSE; Folstein, Folstein, & McHugh, 1975) to ensure there were no major cognitive impairments. [4] All participants were given a packet with instructions for the memory load task and the speaker task. Figure 5 shows the first block of trials for each participant.

[4] I do acknowledge that it would be preferable to also have the young adult participants complete the MMSE, however, the decision to include older adults in this study came after I began running younger adult participants. Excluding older adults with major cognitive impairments should actually reduce age differences.

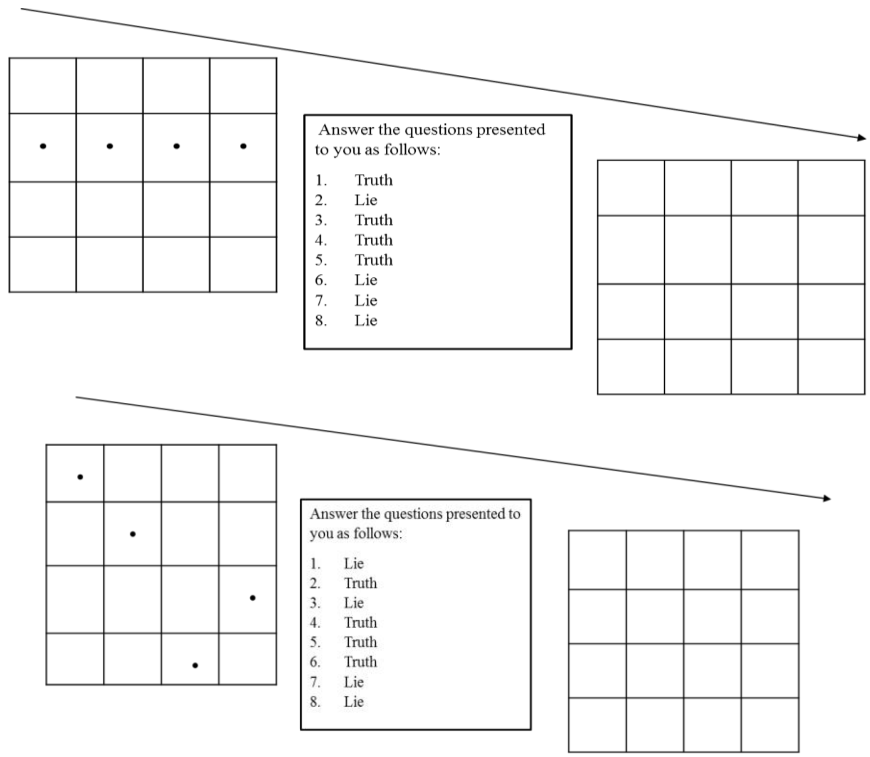

Figure 5. Sample of a speaking trial under low memory load (top) and high memory load (bottom).

After all the speaker videos were collected, detectors viewed them. Two young adults, a 24-year-old female and a 25-year-old male, from outside the lab volunteered to be detectors. The detector's goal was to determine if the speaker was lying or telling the truth.

<u>Materials</u>

The materials used in Experiment 2 were the same as those used in Experiment 1, except for four minor changes. First, participants played the role of the speaker only. Second, I removed any exit survey questions referring to a partner. Third, for older adults only, the MMSE (Folstein et al., 1975) was administered to ensure there were no pervasive cognitive impairments. Finally, five of the 64 initial questions were slightly altered so that they applied to an older adult and not to a college student.

MMSE. The MMSE is a brief 30-point exam used to expose a possibility of cognitive impairment in older adults. It examines orientation, registration, attention, recall, language, repetition and complex demands. Any score below 24 suggests that there might be a cognitive issue and the data for this participant should be discarded.

Packet. Participants were given packets in which the procedure was clearly explained. The packets were 16 pages total. The first 2 pages contained the 64 one-to-two answer questions that were answered once. The following 5 questions were changed:

Originally phrased question	Altered phrasing for older adults
What is your intended major?	What was your major when you attended college?
How many class periods do you have in a week?	How many classes do you attend in a week?
How many kids do you want to have?	How many kids do you have?
At what age do you plan on getting married?	At what age did you get married?
When was the last time you spoke to your parents?	When was the last time you spoke to your parents/children?

If participants did not attend college, they wrote that as their response. Additionally, if the participant never married or never had children, they would record this as their answer.

Participants saw a packet similar to the packet in Experiment 1. The only change in each block was the omission of the “detection” page, because the detector was replaced by a camera (see Figure 5). The last page of the packet was an exit survey which examined several aspects of their performance.

Exit Survey. An exit survey was completed with the questions "Do you believe you are a good liar? Why?" "Do you think you are good at catching lies? Why?" These questions served as a qualitative report on how well participants believe they tell and catch lies.

Results

Data Scoring

As in Experiment 1, OSPAN and RSPAN scores were first transformed to Z-Scores. The WMC composite score was created by averaging standardized OSPAN and RSPAN scores and used in the subsequent analyses. Furthermore, compliance, discriminability, and criterion were calculated in the same way as Experiment 1.

Memory Task. As a manipulation check, I examined the effectiveness of the low vs high load task, as in Experiment 1. A pair samples t-test revealed participants remembered more easy matrix dots (*M*=7.74) than hard matrix dots (*M*=6.47). I also conducted an ANOVA examining if there were any age differences in the ability to remember the matrices by using Load (High load Matrix vs Low load Matrix) as a within subjects factor and Age (Young vs Old) as a between subject factors. There was a main effect of load $F(1,92)=37.588$, $MSE=72.465$, $\eta_p^2=.290$, such that high load matrices were harder to remember than easy load matrices. There was also a main effect of Age $F(1,92)=7.410$, $MSE=12.513$, $\eta_p^2=.075$, such that older adults remembered fewer dots than younger adults. There was no Load x Age interaction, $F(1,92)=0.021$, $MSE=0.040$, $\eta_p^2=.000$.

<u>Compliance</u>

All significant effects are associated with a two-tailed $p<.05$. First, I examined younger and older adults' ability to comply with the task. I used a repeated measures ANOVA with Load (High vs Low) and Response Type (True vs Lie) as the within subjects factor and Speaker WMC (a composite of RSPAN and OSPAN scores) as a covariate. For younger adults, there was a main effect of Load $F(1,55)=4.136$, $MSE=2.320$, $\eta_p^2=.070$, such that a higher load increased the ability to comply (see Figure 6). There was also a main effect of Response Type, $F(1,55)=13.762$, $MSE=14.25$, $\eta_p^2=.200$, such that compliance was greater when telling a lie. There was no overall effect of WMC, $F(1,55)=.771$, $MSE=1.014$, $p=.384$, $\eta_p^2=.014$. For older adults, there was a main effect of Response Type $F(1,32)=43.192$, $MSE=90.588$, $\eta_p^2=.574$, such that it was easier to comply when telling a lie. There also was a significant Type x Load interaction, $F(1,32)=4.838$, $MSE=2.659$, $\eta_p^2=.131$, such that telling lies was equal across loads but participants had an easier time telling truths in the high load condition than in the low load (see Figure 6). There was no effect of WMC, $F(1,32)=.138$, $MSE=.274$, $p=.712$, $\eta_p^2=.004$.

I next examined the effects of Age, Load and Response Type to see if there are any age differences in compliance. A Repeated Measures ANOVA was used with Load (High vs Low) and Response Type (Lie vs True) as within subjects' factors and Age (Young vs Old) as a between subjects' factor. Here, I found a mean difference in Age $F(1,89)=24.481$, $MSE=9.425$, $\eta_p^2=.216$, such that older adults found it more difficult to comply than younger adults. There was a main effect of Load, $F(1,89)=6.854$, *MSE*=4.931, η_p^2=.072, such that compliance was greater under high load. There was a main effect of Response Type, *F*(1,89)=69.416, *MSE*=96.835, η_p^2=.438, such that compliance was greater when telling a lie. I also found a significant Response Type x Age interaction, *F*(1,89)=19.575, *MSE*=27.307, η_p^2=.180, such that there were no age differences on compliance when lying, but older adults complied much less than younger adults when telling the truth (see Figure 6). Lastly, I found a significant Load x Response Type Interaction, *F*(1,89)=4.774, *MSE*=2.735, η_p^2=.051, such that the drop in compliance when telling the truth was exaggerated under low load (see Figure 6). The three-way interaction between Age, Load and Response Type was non-significant, *F*(1,89)=1.949, *MSE*=.856, *p*=.225, η_p^2=.017.

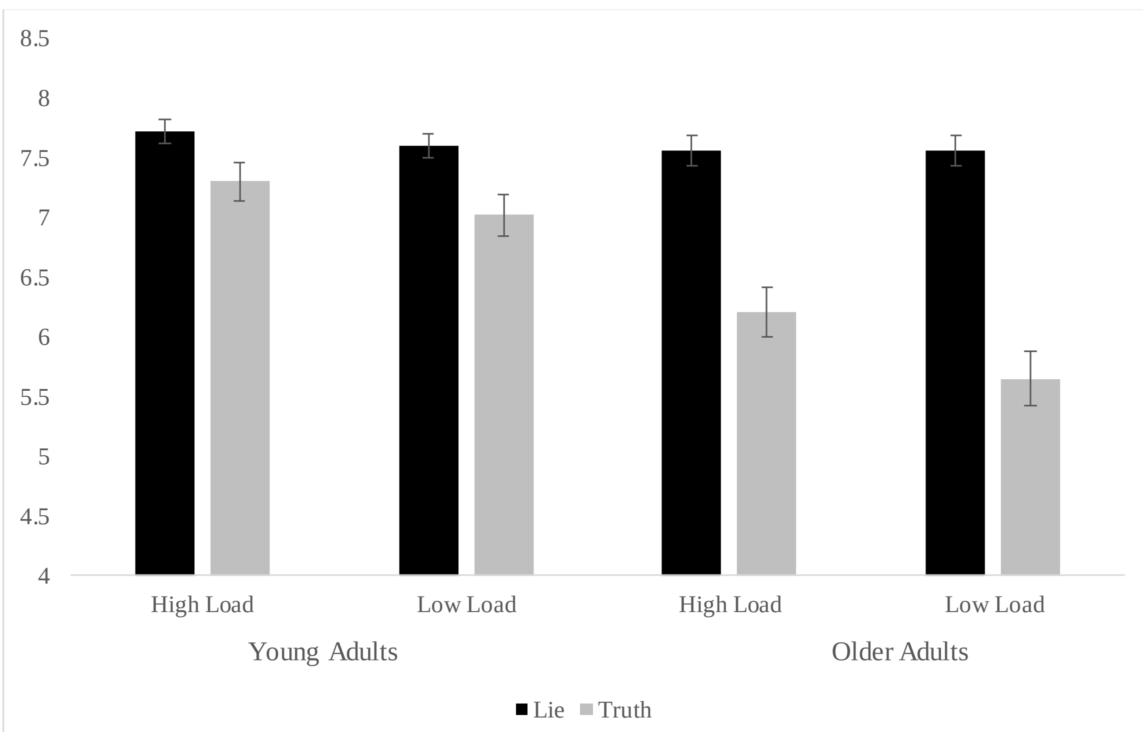

Figure 6. Younger and Older Adults ability to comply by Load and Response Type.

Lie Detection Performance

I next examined WMC's influence on deception ability for younger and older adults. I conducted a repeated measures ANOVA of d' using load (high and low) as a within subjects variable and Speaker Span as a covariate. There were no effects of WMC on deception for either younger [$F(1,55)=.607$, $MSE=.187$, $p=.439$, $\eta_p^2=.011$] or older adults, $F(1,32)=.017$, $MSE=.010$, $p=.896$, $\eta_p^2=.001$.

I next looked at the influence of Age and Load on the ability to convincingly tell a lie. I conducted a repeated measures ANOVA using Age (Young vs Old) as a between subjects' factor and Load (High vs Low) as the within subjects' factor. There was no effect of Age $F(1,89)=1.966$, $MSE=.769$, $p=.164$, $\eta_p^2=.022$ or Load $F(1,89)=.034$, $MSE=.008$, $p=.855$, $\eta_p^2=.000$ on the ability to deceive.

As in Experiment 1, I also examined the relationship between speaker's RSPAN and detectability under load. For younger adults, there was no significant relationship under either high $r=-.186$, $p=.167$ or low load, $r=-.106$, $p=.434$ (See Table 1, row two). Similarly, for older adults, there was no significant relationship under either high $r=-.070$, $p=.695$ or low load, $r=.011$, $p=.951$ (See Table 1, row three).

Next, linear regressions were calculated to predict one's ability to tell convincing lies under a high and low cognitive load using Age and WMC as predictors. I did not find a significant regression equation for either high load $F(2,90)=2.303$, $MSE=0.646$, $p=0.106$ (see Figure 7) or low load, $F(2,90)=0.255$, $MSE=0.089$, $p=0.776$ (see Figure 8).

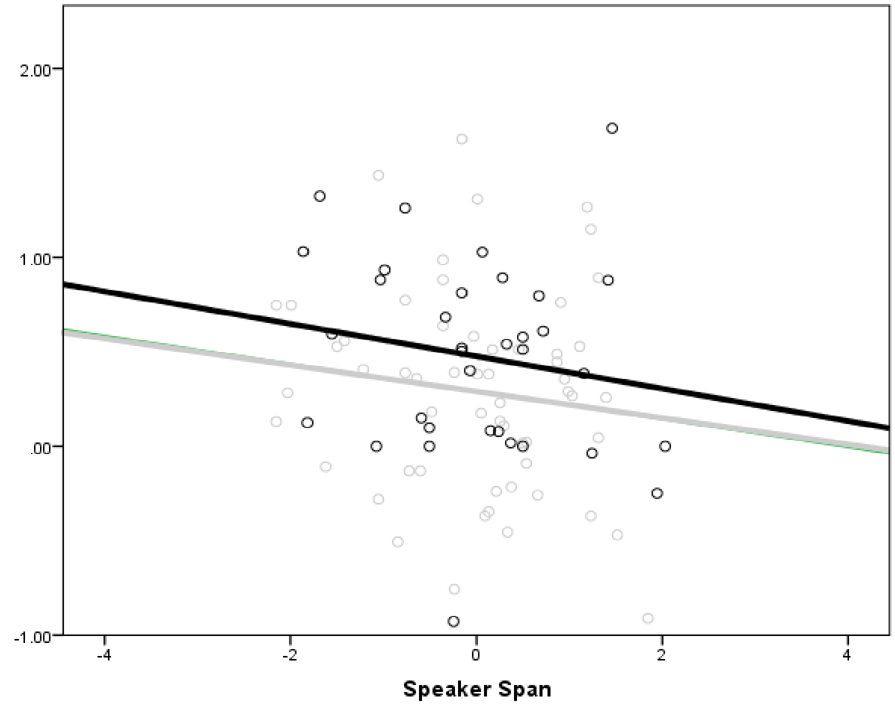

Figure 7. Age (old, black; young, grey) and WMC's ability to tell a lie under high load.

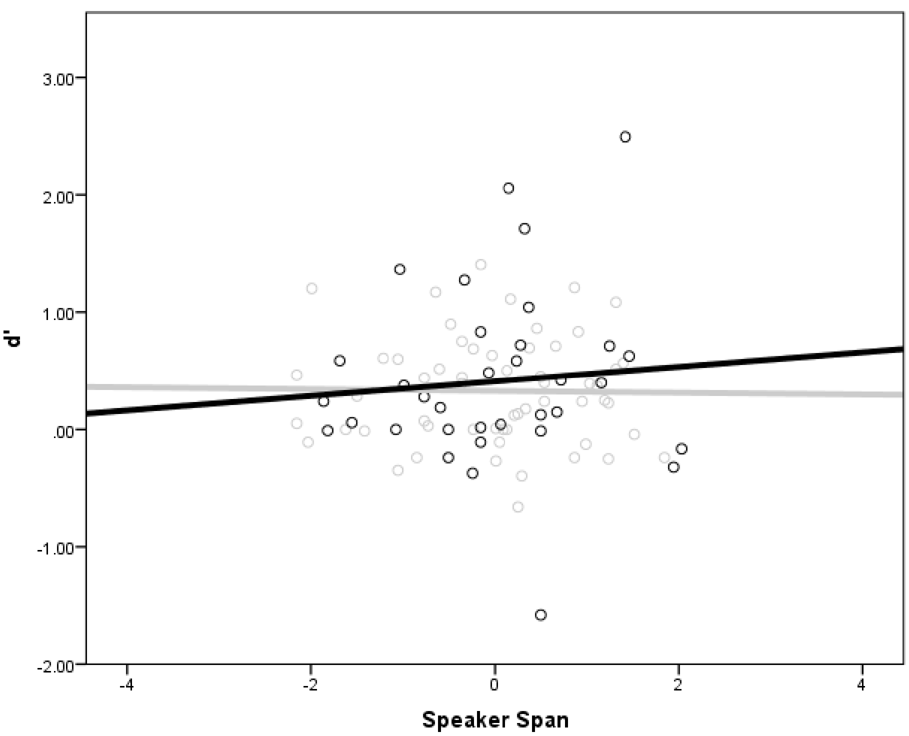

Figure 8. Age (old, black; young, grey) and WMC's ability to tell a lie under low load.

As in Experiment 1, I was again interested in the relationship between detection and dot memory. Memory for low load dot matrices across both younger and older adults did not correlate with detection under high (r=-.073, p=.491) or low load (r=-.103, p=.329). Similarly, memory for high load dot matrices did not correlate with detection under high (r=.007, p=.950) or low load (r=-.161, p=.128).

I was also interested in overall detectability. This was done by taking the average of the hit rate and the correct rejection rate. Overall, Detector 1 had a 56% detection rate for younger adults and a 58% detection rate for older adults. Detector 2 had a 55% detection rate for younger adults and a 58% detection rate for older adults. One sample t-tests confirmed overall detectability was significantly greater than chance for both younger and older adults (ts>3.5, ps<.05).

The last analysis examined inter-rater reliability between the young adult detectors. When rating younger adults, the raters had significant reliability under both low load, $r(57)$= .355, and high load, $r(57)$= .792 conditions. For older adults, the raters had significant reliability under low load, $r(34)$= .635, but not under high load, $r(34)$= -.020.

Combined Young Adult Detection. In Experiment 1, I saw a significant negative relationship between younger adult speakers' RSPAN and d' under high load, but in Experiment 2, this effect does not reach significance. However, when the RSPAN scores for young adults are combined across experiments and re-standardized, the significant negative relationship remains, r=-.220, p<.05 (See Table 1). This demonstrates that higher RSPAN scores are indeed associated with less detectability across experiments.

Discussion

In Experiment 2, I was interested in understanding the relationship between deception, cognitive load, WMC and age, while holding the detector constant. In holding the detector constant, I reduced random error produced through differences in detector characteristics. I hoped controlling for detector differences would provide a clearer picture of WMC's role in deception. Furthermore, deception research does not often include older adults. Therefore, I wanted to examine the relationship between deception in younger and older adults to see if deception ability changes across age groups.

For compliance, I found that younger adults were more likely to comply under high load or if they had to respond with a lie. Older adults were also more likely to comply if they had to tell a lie, especially under high load. When I added Age as a between subject's factor, I continued to see that having to respond under high load or having to respond with a lie increased the likelihood of compliance. I also found that older adults had a harder time telling truths than lies, whereas younger adults did not. Lastly, there is a drop in compliance when telling the truth under low load. Similar to Experiment 1, participants had an easier time responding to lies, presumably because there is no need to remember an exact response. Furthermore, participants complied more under high load than under low load. This could be the result of increased cognitive resources used to complete a task under a high cognitive load.

For deception, I did not see any differences in ability to deceive, regardless of WMC or age. These findings might be because of a weak load manipulation or because the lying task was not as difficult as it could be. A higher load might polarize younger and older adults, such that younger adults might handle the added load whereas older adults' performance deteriorates. Furthermore, because telling the truth was apparently more difficult, poor memory could have caused participants to forget their truthful response. Requiring participants to tell stories, instead of a simple one or two-word answer, might make it more difficult for participants to remember their lies. Therefore, increasing WMC's involvement in the task can polarize WMC's influence on deception such that those with higher WMC should handle remembering all the story details better than low WMC individuals.

It is important to emphasize that, when I combined young adult speakers' RSPAN and detectability across the two experiments, high RSPAN scores were significantly related to less detectability. This finding is exciting because it shows that there is a relationship between WMC and the ability to deceive, such that higher WMC individuals do have the ability to convincingly tell a lie while under additional load. This relationship should be explored to better understand what underlying mechanisms are influencing this relationship.

Whereas the combined data show a relationship between WMC and the ability to deceive, the inter-rater reliability data also show individual differences in the ability to deceive. Inter-rater reliability examines the extent to which raters agree in their ratings. Higher reliability ratings indicate higher rates of agreement across raters. Between the raters, there was significant inter-rater reliability. This demonstrates that there are individual differences in lying ability, such that convincing liars were able to deceive both raters similarly whereas the detectors tended to detect lies from the same individuals. Further, the detectors did not detect 100% of the lies, indicating that some of the participants were convincing lairs. Had the participants all been convincing, undetectable liars, there would be no inter-rater reliability because the detectors would have to detect by random guessing.

GENERAL DISCUSSION

Historically, deception has been viewed through an arousal-based lens (National Research Council, 2003). Not until recently has cognitive ability been examined in deception (Vrij, 2008). Furthermore, there is little research examining the relationship between deception and age. In two experiments, I explored the relationship between WMC, cognitive load, age and deception. The goal was to understand what advantage high WMC individuals had, if any, on their ability to tell and detect lies. I was also interested in understanding how this relationship potentially changed as we age.

In Experiment 1, I examined deception, cognitive load and WMC in young adult dyads. I found that higher WMC individuals comply more with the task, such that they were able to provide a truthful or deceitful response when asked. Furthermore, participants complied more when they had to tell a lie. In terms of deception, overall, detectors were able to detect lies at a level significantly greater than chance. I also found a Speaker WMC x Detector WMC x Load interaction related to improved ability to deceive. Upon further investigation, under low load, the relationship between the speakers' and detectors' WMC predicted the ability to lie such that high WMC speakers had fewer lies detected by high and medium WMC detectors. However, when high WMC speakers spoke to low WMC detectors, they saw more of their lies detected. I also examined the speaker's RSPAN score and detectability under load which demonstrated that high RSPAN scores were associated with less detectability when under high load.

In Experiment 2, I kept the detector constant, and examined how age influences peoples' ability to deceive. I found that younger adults complied better with instructions under a low load or when they had to tell a lie. Older adults also found it easier to comply with instructions when they had to tell a lie, especially under high load. For both older and younger adults, there was a drop in compliance when telling the truth under low load. Additionally, older adults had more difficulty providing a truthful response than younger adults. Further, although participants found lying easier than telling the truth, neither WMC nor age predicted the ability to deceive. For deception, detectors were again above chance. Importantly, there was significant inter-rater reliability which suggests there are individual differences in the way people deceive, supporting the need to further explore individual difference measures, like WMC, for deception.

When I combined young adult data from Experiment 1 and 2, I found that higher speaker RSPAN was associated with less detectability, suggesting WMC does influence how someone deceives, such that higher RSPAN scores are associated with less detectability. However, because I combined data across experiments and I am evaluating correlational data, I do not have the control or the evidence necessary to imply causation. Nonetheless, this result is still important because it shows that high scores on a verbal measure of WMC is related to better lying, also a verbal task. Understanding that measures in the verbal domain relate to deception allows us to identify tasks, like the RSPAN, that are suitable for examining underlying mechanisms of deception.

Working Memory Capacity Abilities and Deception

The data does not provide a clear explanation on how much of each WMC-related ability is required to convincingly tell a lie. It is plausible to believe that all four are required, but situational differences might influence how much of one ability is used.

This is explicitly demonstrated across the two experiments presented in this thesis. Experiment 1 loosely represents a real life scenario in which individuals lie to each other. Here, the liar must monitor their own behavioral cues, but must also monitor their partner's behavioral cues, all while monitoring their lie. This should require an extensive amount of multitasking. However, in Experiment 2, the liar only needs to lie to a camera, therefore only needing to monitor their own behavioral cues, while monitoring their lie. In both experiments, multitasking is required, but the extent to which it is used varied. This could perhaps explain why the correlation between RSPAN and lie detection under high load did not reach significance in Experiment 2.

Further, maintaining the task goal is another integral part of deception. Without maintaining the task goal, the whole venture to tell a lie might collapse due to poor performance (Spieler, Balota, & Faust, 1996). Older adults, in particular, often failed to maintain the task goal, as evidenced by the overall effect of Age on task compliance in Experiment 2. This is particularly interesting because, in Experiment 2's paradigm, one's necessary response type was always provided for them. This suggests that the task goal was lost in a short amount of time. Further, this might suggest that older adults might not have issues with maintaining the goal, but instead with task switching between telling a truth and a lie is difficult. This could suggest task switching as a fifth ability necessary for deception.

Additionally, when the goal to lie is developed and an individual maintains this goal, the next step is to monitor for conflict. Failure to monitor conflict can lead to a decrease in performance (Botvinick et al., 2001; Botvinivk, Cohen, & Carter, 2004). Conflict monitoring was experienced in both experiments and logically is a staple in deception. Providing a truthful response or divulging inconsistent information increases the possibility the liar gets caught. While only anecdotal, older adults had difficult monitoring for conflict such that there was visible turmoil such as visual frustration or disappointment in how they responded to questions.

Lastly, inhibiting dominate responses is easily understood as a crucial component to lying. Failing to inhibit a response could degrade performance, such that a failure to inhibit a truthful response increases the chance of getting caught (Rubia, Smith, Brammer, & Taylor, 2003). Again, while only anecdotal, older adults would often verbally criticize themselves by saying they were supposed to tell a lie or tell the truth but did the opposite. This is again shown in the compliance data, such that older adults had more difficulty complying when having to tell the truth or when under low load.

Taken together, all four abilities play a role in telling a convincing lie, but situational factors influence the extent to which they are used. For example, in the current paradigm, age and experiment (1 vs. 2) influenced how much multitasking one used, but there were no subjective differences in how much inhibition, conflict monitoring or goal maintenance was used. However, in different situations with different people, one might need to monitor for conflict more than inhibit responses, such as in an interrogation in which someone needs to make sure all the information is present in a way that aligns with the lie and the facts.

Future Directions

The main goal for the paper was to understand how WMC influenced someone's ability to tell a lie. I was unable to define a causal relationship between WMC and deceit, but I did find a correlational relationship that suggested higher WMC was associated with less detectability. This is significant because I can now devise paradigms that will intimately examine the underlying mechanisms involved in deception and begin to develop causal relationships that will help clarify the complex nature of deception and what role WMC plays in the relationship. Whereas the outcome of the deception data was not ideal, the data pertaining to compliance might help use develop the necessary paradigms to find these causal relationships between WMC and deception.

A consistent theme across both experiments was that participants complied more when telling a lie than when telling the truth. I suspect that needing to remember a single truthful response was more difficult than responding with a potentially infinite number of lies. This experiment was designed to examine how global WMC would influence the ability to tell a lie, but the paradigm promotes needing attentional control in order to successfully complete the task. Shipstead, Lindsey, Marshall, and Engle (2014) examined WMC as a multi-mechanism construct, instead of a unitary construct that can be explained by one mechanism, like attentional control. Shipstead et al. suggest primary memory, secondary memory and attentional control compose a multi-mechanism model that explain individual differences in WMC. The authors describe primary memory as a limited capacity storage that maintains 3-5 items at any time, similar to short term memory (Luck & Vogel, 1997; Cowan, 2001). Attentional Control allows someone to focus on the current task and helps maintain primary memory by selecting goal-relevant information, instead of information that will distract the participant. Secondary memory is the long-term storage system from which information is drawn, similar to long term memory (Unsworth & Engle, 2007). Based on Shipstead et al.'s framework, the participants in the current paradigm would need primary memory to handle the load matrix and attentional control to focus on answering the questions appropriately. But participants would also need to successfully retrieve information in secondary memory to remember the truthful answer they wrote at the beginning of the experiment. In Experiment 2, there were age differences in compliance, such that older adults had a harder time telling the truth than younger adults. This could presumably be because of a deficiency in retrieving the factual information from secondary memory.

Therefore, it might be beneficial to create a paradigm to see what role retrieval from secondary memory plays in lying and how that retrieval relates to WMC. This could then allow researchers to understand WMC differences in deception. To do this, it would be beneficial to create a Tangled-Web Paradigm. In this paradigm, one would need to tell a story, and sometime later retrieve the story from secondary memory, bring it into primary memory and recall the story correctly, while using attentional control to ensure the story is delivered accurately and convincingly. Unsworth and Engle (2007) suggest that WMC does not only gauge how well someone can use attention to tune out distraction, but also how well someone can search and retrieve relevant information from secondary memory. In Experiments 1 and 2, participants retrieved information from secondary memory that they experienced 30 minutes prior to the deception task. The Tangled-Web Paradigm would exaggerate the time between the time the story was told and the time the story needs to be retold, which should make searching and retrieving the information from secondary memory more difficult, presumably due to greater interference during this time. This would be one more layer of complexity in the deception task and can provide more opportunity for detection, because not only must the liar convincingly restate the lie without changing any facts, in addition to combatting a cognitive load, but must also retrieve task relevant information from secondary memory that was experienced several days prior. This is a task that seems suited only for those who are high WMC individuals and could put a spotlight on any missed WMC effects in the current paradigm, especially those due to secondary memory. Furthermore, this would mimic a real world scenario of deception and could shed light on how WMC and deception relate over time.

A second theme that emerged was that participants were more likely to comply if they were under high load. This is opposite of what would be expected, because the extra load should have decreased ability, not improved ability. However, unpublished eye tracking research (Hutchison, Hart, Moffitt, & Marchak, 2015) found that high WMC individuals had larger pupil diameter, an indication of a larger exertion of effort, in anticipation of a difficult trial relative to an easy trial. In regard to lying, it is possible that participants prepare for each trial differently, such that during a hard matrix trial there is an attempt to recruit more resources, which could improve performance. But, when an easy trial comes, these participants relax, causing performance to suffer. Perhaps using eye tracking techniques will allow us to understand how people prepare to tell a lie and if this preparation leads to more convincing lies. I can then also see if there are WMC differences in preparation and development of convincing lies.

This theme could also have relevance on how deception is researched and applied in the legal system (Ekman & O'Sullivan, 1991; Ekman et al., 1999). Judges, law enforcement, and psychiatrists were no better than chance in detecting lies. Their main job is to ensure safety by uncovering the truth. If someone's main job is to uncover the truth, and they are no better than chance at doing so, immediate changes need to be implemented. Some research (Vrij, 2008) is calling for a push to use a Cognitive Load Approach when detecting deception and the judicial system is the direct recipient of this push (Vrij, 2008). But, this new understanding of cognitive load and its relationship to deception should suggest caution in this movement. The current results suggest managing a high cognitive load might improve performance. Therefore, it is possible that the cognitive load approach is influencing truth telling behavior and not deceptive behavior and detectors are picking up differences in truthful cues and not lying cues. Fenn, Blandón-Gitlin, Coons, Pineda, and Echon, (2015) found that when participants needed to hold their bladder, they were more likely to successfully tell a lie than when they had to tell a lie with an empty bladder. Fenn et al. (2015) explain this is the result of the Inhibitory-Spillover-Effect. This effect results when the performance on one self-control task facilitates performance on another self-control task conducted at the same time. Therefore, physical inhibition exerted when holding one's bladder should facilitate cognitive inhibition when lying, resulting in less lie detection. Taken together, Fenn et al. (2015) and the current results would suggest that increasing the need to exert control to monitor performance could improve the ability to deceive. Therefore, it is important that more research is given to the Cognitive Load Approach and ensure it is a useful tool. Otherwise, individuals who are already poor at detecting lies are provided with a security blanket that does not provide security. It potentially provides a bigger chance for someone to tell a convincing lie and get away with it.

Lastly, I did not see any age differences in telling lies. The older adult literature on deception is limited and inconsistent. Some data suggests that older adults can detect lies better than chance (Parham et al., 1981; Bond et al., 2005) but other data suggest older adults are poor lie tellers and detectors (Ruffman et al., 2012). Serota, Levine, and Boster (2010) found that, with increased age, the number of lies told in a 24-hour period decreased. This could suggest that less practice would decrease their ability to tell a lie. Further, James, Boyle, and Bennett (2014) found susceptibility to deception was positively associated with age but negatively correlated with income, cognitive ability, psychological well-being, social support and literacy. The data would suggest that a decline in secondary memory and not overall WMC could cause issues with deception, supporting the previously found negative relationship between susceptibility and cognitive ability. Therefore, future research should explore how cognitive measures specific to memory in older adults relate to deception. In a similar vein, understanding how susceptible older adults are to deception also provides an opportunity to develop training programs so that older adults do not fall victim to these scams. Taken together, these data might hint at the possibility that issues in deception for older adults lie in secondary memory and not necessarily inhibition ability. Subjecting older adults to the Tangled Web Paradigm might allow us to better understand if memory really is the issue for deception in older adults or if another avenue should be taken.

Conclusions

The primary focus for these experiments was to understand what role WMC, cognitive load and age played in one’s ability to tell and detect lies. No effect of WMC or age on deception were found. However, more research is required to get a complete understanding of age and WMC’s role in deception.

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