PUPIL RESPONSE AS A MEASURE OF PREPARATORY CONTROL OF ATTENTION IN ANTICIPATION OF DECEPTION

by

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ABSTRACT

Deception is generally considered to be more cognitively demanding than telling the truth, driving research interest in the relationship between deception and cognitive ability. Few studies have explored the preparatory attentional state occurring after the decision to be dishonest is made, but before the content of the question is known to the deceiver. Participants in the current study were given "Truth" or "Lie" prompts several seconds before being asked questions about autobiographical information that they answered according to the prompt. Cue-evoked pupillary responses, or the changes in participants' pupils during the fixation period between the prompt and question presentation, served as an objective physiological measure of this preparatory state of attention. To assess cognitive ability, several tasks assessing working memory capacity and attentional control were also administered to determine their relationship with pupil response. Aligned with results from a former study, it was hypothesized that pupil diameter would be greatest in anticipation of "Lie" trials, that working memory capacity and attentional control would be negatively correlated with the proportion of errors committed and positively correlated with pupil size in the final few seconds of the fixation interval, and that pupil diameter variability across the fixation interval would be positively correlated with the proportion of errors committed. Results showed a general pattern of constriction in pupil diameter in the fixation interval, which opposed results from previous studies, and did not provide support for the main hypotheses. Lie trials where participants committed an error displayed a significant decrease in pupil diameter across the fixation interval relative to accurate lie trials. Possible reasons for general pattern of pupil constriction are given, prompting a retesting of the hypotheses under better experimental conditions. It is still possible that there is a general pattern of pupil dilation in this preparatory period.

CHAPTER ONE

INTRODUCTION

Pupil Response As A Measure Of Preparatory Control Of Attention In Anticipation Of Deception

Deceiving, or telling a lie, is generally considered to be more cognitively demanding than telling the truth (Garcia et al., 2023; Gombos, 2006; Vrij et al., 2006, 2017). Once truthful information is activated from the memory of the deceiver, every action that follows including the decision to be dishonest, the construction of a falsehood, and the delivery of a lie (Walczyk et al., 2014), can elicit cues to deception (DePaulo et al., 2003) from the face, body, or voice (Zuckerman et al., 1981). The sequence of events involved in fabrication of dishonest messages as outlined by Walczyk et al. (2014) implies that successful deception involves both efficient maintenance and inhibition of truthful information, both domain general cognitive functions that rely on an ability to control one's attentional state (Engle, 2002, 2018). Each segment of this deception sequence taxes cognitive mechanisms more than when one is telling the truth, imposing an intrinsic cognitive load upon the deceiver (Walczyk et al., 2013). This additional cognitive load is reflected in increased verbal and behavioral reaction times (RTs) found across multiple different experimental paradigms (Suchotzki et al., 2017), and increased levels of arousal captured by neuroimaging (Meijer et al., 2016) and skin conductance response (Stöfer et al., 2015) measures.

The notion that lying is theoretically more cognitively demanding than telling the truth has inspired research attempting to correlate behavioral measures of deception like RTs and errors with scores on tasks assessing various executive functions, defined as "general purpose control mechanisms that modulate the operation of various cognitive subprocesses and thereby regulate the dynamics of human cognition” (Miyake et al., 2000, p. 50). Two executive functions often correlated with lying ability are working memory capacity (WMC; Lo & Tseng, 2018; Maldonado et al., 2018), or “the ability to maintain and manipulate information” (Mashburn et al., 2022p. 154), and inhibition (Visu Petra et al., 2012, 2014), or “the deliberate, controlled suppression of prepotent responses” (Miyake et al., 2000, p. 58). Additionally, brain-imaging measures (Christ et al., 2009) and measures of the electrical activity of the brain (Farwell & Donchin, 1991) have attempted to discriminate the complexity of lying relative to telling the truth. Most of these studies measured the response-related changes observed in some behavioral or physiological measure that occurred once a stimulus was presented or a question was asked. Although findings from these studies are thought to reflect the cognitive complexity of lying when responding to questions, they did not capture any potential differences in physiological arousal occurring before a question is asked that would indicate a preparatory state of controlled attention preceding deceptive responses. If these differences exist, they may further bolster the notion that lying is more cognitively demanding than telling the truth, in that individuals would demonstrate heightened control of attention prior to deceptive relative to truthful responses. Naturally, the question of what physiological measure might best capture this preparatory state of attention needs to be addressed.

Pupillometry, or the measure of change in pupil diameter, may serve as a reliable method of assessing the cognitive load involved in deception (DePaulo et al., 2003; Zuckerman et al., 1981). Pupillometry is shown to effectively measure cognitive effort (Hess & Polt, 1964; Peavler, 1974), task difficulty (Kahneman & Beatty, 1966; Rondeel et al., 2015), differences between truth and lie responses observed between participants guilty and innocent of mock crimes (Cook et al., 2012; Webb et al., 2009), and truth and lie response differences given to emotionally neutral questions (Dionisio et al., 2001). A recent study used pupillometry to measure this preparatory state of attention when participants were anticipating trials of varying difficulty in the antisaccade task, finding that the changes in pupil diameter accurately captured individual differences in controlled attention and predicted performance (Hood et al., 2022). This suggests that measuring changes in pupil size could similarly capture participants' attention and predict their performance for other tasks as well, like when they are preparing to lie or tell the truth to upcoming questions. In addition, Hood et al. (2022) demonstrated differential pupil response patterns between participants high and low in WMC. Given the association between WMC and deception observed in previous studies, this finding warrants the investigation of the relationship between WMC and cue-related changes in pupil size in the current study. Also, because individual differences in WMC are thought to be dependent on one's ability to control attention (Engle 2002, 2018), and because we are investigating a state of preparatory attention, the current study is interested in the relationship between deception and attentional control (AC), an executive function conceptually similar to inhibition defined as the "domain general ability to regulate information processing in the pursuit of goal-directed behavior" (Burgoyne & Engle, 2022, p. 624).

In the following, behavioral measures assessing the cognitive complexity of deception and their relationship with WMC, inhibition, and physiological response measures are explored. Then, empirical evidence of pupil response as a measure of cognitive effort and as a method of classifying subjects as deceptive or truthful is discussed. Finally, a study was conducted to determine the relationship between individual differences in WMC, AC, and changes in pupil size during an interval in which participants knew they would lie or tell the truth to an upcoming question, without knowing what question would be asked. In this way, we can isolate the decision component from the ADCAT theory (Walczyk et al., 2014), as this component would be the only contributor to potential response-related differences in pupil size preceding questions. This allows for a better understanding of how this component may contribute to the theorized cognitive complexity characteristic of lying relative to telling the truth.

Deception, Executive Functions, And Behavioral Measures

The activation – decision – construction – action theory (ADCAT; Walczyk et al., 2014) posits that lying ability is determined by accurate and automatic memory for the truth, and that the automatic nature of delivering truthful information can cause "Stroop-like interference" (p. 31) effects when the incompatible action of lying is carried out. This is in reference to the Stroop task in which participants are instructed to name the color in which words are written, with the words' meanings being either matched (congruent) or mismatched (incongruent) with their written colors (Stroop, 1935). It is much more common for participants to produce longer RTs and more errors on incongruent trials, indicating they are more difficult than congruent trials, requiring heightened AC. This analogy suggests parallel cognitive mechanisms fundamental to these tasks in which individuals must inhibit an automatic response while executing a controlled response.

Due to its conflicting nature with the truth, and its reliance on memory, researchers have examined the relationship between deception and WMC, as WMC is thought to require short-term storage of information and AC (Engle, 2002, 2018). Scores on tasks of WMC in which participants must perform a primary task, like solving math problems or determining the sensibility of sentences, and a secondary task, like retaining letters to recall after a variable number of trials, are sometimes correlated with dependent measures of deception. Other tasks of inhibition (e.g., Stroop task) are also highly correlated with dependent measures of deception, as these tasks assess one's ability to override an automatic and prepotent response. According to the ADCAT theory, the truth is the default or automatic response (Walcyzk et al., 2014), meaning those high in inhibition would likely be more successful at overriding the natural tendency to tell the truth. Lying ability has been assessed in these studies by measuring participants' RTs and errors when answering questions. Like the finding that RTs are longer for incongruent trials in the Stroop task, RTs are longer for deceptive responses in experimental deception tasks as well. There are mixed findings regarding the differences in errors committed between truth and lie responses experimentally. However, studies that assessed cognitive ability showed that participants high in WMC and inhibition tend to produce quicker RTs and commit less errors than participants low in WMC and inhibition.

WMC

Investigating the relationship between WMC and lying ability, Lo and Tseng (2018) had participants study lists of words and then make truthful and dishonest recognition judgments over several trial blocks in a subsequent test phase while their RTs and accuracy were measured. Specifically, participants had to make truthful and dishonest old/new judgments to words based on a color-cued prompt that preceded the word's presentation. After this task, participants completed both the operation span (OSPAN) and symmetry span tasks to assess verbal and visuospatial WMC, respectively. Participants' RTs for deceptive responses to old words, and the difference in RTs between deceptive and truthful responses to old words, were both negatively correlated with OSPAN scores, but not symmetry span scores. These results suggest that lies constructed from highly accessible truthful information may be more related to verbal than visuospatial WMC, as those with higher OSPAN scores produced quicker deceptive responses and decreased RT differences between truthful and dishonest responses to previously studied words, but no such relationship was shown for symmetry span scores. Furthermore, participants were less accurate in the last few trials of each block, suggesting forgetting was more common in later trials when performing this task. However, accuracy in the last half of blocks of trials was also positively correlated with OSPAN scores, but not symmetry span scores. Together, these results suggest WMC as a moderator of lying ability, in that participants high in WMC have better memory for truthful information and can quickly produce deceptive responses relative to participants low in WMC. This suggests that if lying is more cognitively demanding than telling the truth, this additional cognitive demand is better managed by individuals high in WMC.

Maldonado et al. (2018) also investigated the relationship between WMC and lying ability. Participants completed the OSPAN and reading span (RSPAN) tasks to assess WMC, and then answered autobiographical questions truthfully and dishonestly under both a high and low cognitive load manipulation while being detected. Cognitive load was induced by having participants retain a sequence of four dots from a matrix presented prior to eight question blocks of trials that were either in a straight line (low cognitive load) or scattered (high cognitive load), and then recalling the dot sequences after answering the full block of questions. Lying ability was assessed by participants' detectability, or the probability of others correctly judging their lie responses, and errors committed during trials. Low WMC individuals' lie responses were more detectable while they were under high cognitive load, and this interaction was driven exclusively by scores on the RSPAN task, and not the OSPAN task. The authors reasoned that sentence processing was essential for both the RSPAN and deception tasks, possibly explaining why it, and not the OSPAN, drove the interaction between cognitive load and WMC on detectability. Additionally, and counter to the notion of lying being more cognitively demanding than telling the truth, participants committed more errors when responding to truth trials than to lie trials. This was suggested as reflecting the memory processes necessary for deception, with some of the questions asking for less rehearsed autobiographical information (e.g., “What would you bring with you to a deserted island?”), potentially causing participants to forget their original truthful answers. This interaction was also driven by scores on the RSPAN task, with participants high in RSPAN scores committing less truth errors than participants low in RSPAN scores.

Although RTs were not measured in this study, the finding that high WMC participants were less detectable under high cognitive load suggests these individuals were more convincing liars. This notion is bolstered by the manipulation check that asked participants what they thought constituted a good cue to deception, with the best detectors most often mentioning RTs or something suggesting RTs (e.g., “hesitation”). This would suggest that the ability to evade detection may have been driven by the ability to produce quicker lie responses that did not noticeably differ from the RTs produced on truthful responses. As in Lo and Tseng (2018), results from Maldonado et al. (2018) suggest WMC may moderate lying ability, in that those low in WMC were more detectable under high cognitive load, and committed more errors when attempting to be truthful, potentially giving the impression of dishonesty.

Inhibition

Other studies measuring inhibition have often found it to be highly associated with deceptive RTs and errors. For example, Battista et al. (2021) showed that relative to participants scoring low, participants scoring high on the Go-No-Go task had a larger proportion of correctly recalled details and smaller number of errors committed in a paradigm in which independent groups had to tell the truth, falsely deny, or lie to all questions about a previously viewed video depicting a crime being committed. This finding was determined across two interviews, one right after viewing the video, in which participants were only questioned about the video, and another 48-hours later, in which participants were questioned about both viewing the video and the initial interview. This would suggest a better ability to override a prepotent response, like telling the truth about viewing the video when initially questioned, is associated with increased capacity for memory encoding, enhancing retrieval during the second interview.

Other studies assessing deception ability and inhibition have used paradigms in which participants are “guilty” or “innocent” of a mock-crime, and then are questioned about their involvement while RTs and accuracy are calculated. For example, Visu-Petra et al. (2012) had participants perform the Stroop task, and then created efficiency scores as their measure of inhibition calculated as the proportion of accurate Stroop responses divided by the average RT taken during the task. Then participants were questioned about their involvement in the mock-crime, with a maximum allowable RT of 1,000 ms for each question asked. The inhibition efficiency score was negatively correlated with guilty participant’s RTs to mock-crime-related questions, meaning participants high in inhibition who were lying about their involvement in the mock-crime did so more quickly than participants low in inhibition, indicating better lying ability. In a follow-up study using a similar mock crime scenario, Visu-Petra et al. (2014) showed that greater inhibition efficiency scores were negatively correlated with the difference in RTs between crime-related and crime-unrelated items, meaning participants guilty of the mock-crime did not produce significantly longer RTs on lie responses than on truth responses. This finding again suggests that better inhibition is associated with better lying ability, in that their lies would be harder to detect given they did not take longer to lie than tell the truth.

Deception, Executive Functions, and Behavioral Measures Summary

The RTs and accuracy measures taken in these studies further support the notion that lying is more cognitively demanding than telling the truth, as lies take longer to generate and produce, and participants' ability to accurately recall truthful and dishonest information has been shown as necessary for their performance in these tasks. However, all the measures mentioned as reflecting the cognitive demands of lying relative to telling the truth were assessed in the period when participants were answering questions. No deception studies have correlated behavioral measures with any measures taken prior to questions being asked, when participants may be in a state of anticipating the upcoming question. Furthermore, if participants were cued on how they would answer an upcoming question in a deception study (i.e., they would be cued to answer the question either truthfully or dishonestly), it is undetermined how measures taken during this anticipation period would correlate with behavioral measures taken once questions are answered. In the current study, we seek to determine the correlation between RTs and errors recorded for participants responses and a measure of attention taken in an interval where participants are cued on how to answer the upcoming questions.

The associations between WMC and inhibition demonstrated in these studies suggest that effective lying ability may depend on factors such as accessible memory of truthful information and the ability to effectively inhibit truthful information in the mind while answering deceptively. The studies assessing inhibition were mentioned because inhibition is the closest executive function conceptually to AC, which is the term used in the current study to describe a measure of the ability to control endogenous attention (Engle, 2018). According to the executive attentional control model of WMC (Engle, 2002, 2018), differences in WMC reflect differences in AC, suggesting it is necessary for the maintenance and manipulation of information that is characteristic of WMC. Given the associations mentioned between inhibition and lying ability from previous studies, the current study attempts to correlate measures of AC with lying ability, but particularly how AC and WMC are associated with measures of attention taken in an interval following a cue indicating how participants will answer upcoming questions. In this way, we are able to measure any individual differences in these executive functions during this anticipation period and see how they correlate with behavioral measures taken when participants answer questions truthfully or dishonestly according to the cue.

Deception and Physiological Measures

Brain-imaging measures have also showed differential activity in specific brain regions during both the decision and construction phases involved in lying relative to telling the truth (Mohamed et al., 2006), and this differential brain activity is correlated with brain-activity observed when participants completed WMC tasks. Separate deception studies and WMC neuro-imaging meta-analyses revealed overlapping activation in brain regions when participants were being deceptive and when they performed the *n*-back task that is used to assess WMC (Christ et al., 2009). These brain regions include the dorsal lateral prefrontal cortex, a domain general region implicated in proactive control of attention in anticipation of responding (Braver, 2012; Ito et al., 2012; Nuñez et al., 2005), and the anterior cingulate cortex, which is activated when encountering stimuli that conflict with one's goal state (Botvinick et al., 2001; Kerns et al., 2004). Activation in these brain regions may reflect the cognitive demand of simultaneously suppressing truthful information while fabricating dishonest responses.

There are also differential patterns of electrical brain activity when participants are lying relative to when they are telling the truth. Pattern components of event-related potential waveforms observed using electroencephalography are thought to reflect both deceptive responding and cognitive control. Specifically, a late positive component (P300) found at the parietal scalp site which is thought to reflect familiarity with questions being asked, has been shown to discriminate participants who are guilty relative to participants who are innocent of mock-crimes (Farwell & Donchin, 1991; Rosenfeld, 1999), in that it is larger for guilty participants who recognize crime-related items relative to crime-unrelated items. Larger P300 amplitudes elicited by crime-related items are also usually accompanied by longer RTs when responding and more errors committed, suggesting increased cognitive demand when inhibiting truthful information to produce dishonest responses.

The P300 pattern component is observed in conjunction with an early negative component at the frontal scalp site called the medial frontal negativity (Johnson et al., 2004; Sai et al., 2023) that is observed upon initiation of a behavioral response when questioned about involvement in a mock-crime or when questioned in other experimental deception paradigms. There is also a negative component (Sai et al., 2023) located at the frontal-central scalp site that is observed when stimuli are presented in experimental tasks. Both the medial frontal negativity and frontal-central negative component are demonstrated as being more negative (i.e., larger) when participants are performing deceptive versus truthful trials across various paradigms. These complementary frontal negative components are thought to reflect error and conflict monitoring inherent to the functioning of the anterior cingulate cortex (Botvinick et al., 2001), which would implicate AC as the main executive function being utilized and observed in these measures.

Deception and Physiological Measures Summary

Both brain-imaging and measures of the electrical activity of the brain have demonstrated differential responding when participants were deceptive versus when they were truthful across many experimental paradigms. These differences in brain activity are thought to reflect the additional cognitive demand that is characteristic of deception relative to telling the truth. However, all the studies mentioned assess brain activity either when a question or stimulus was presented, or when a behavioral response was given to a previously presented stimulus. To my knowledge, only two studies measured differential brain activity when a pre-stimulus prompt was presented alerting participants on how to answer to upcoming questions in deception paradigms: Ito et al. (2012) used brain imaging, and Lui et al. (2017) used electroencephalography. Because the current study is interested in the differences in physiological activity between truthful and dishonest responding captured in this pre-stimulus interval, but also because we do not have access to either brain-imaging or electroencephalography technology, and because we needed a physiological measurement method that is conducive to our experimental deception paradigm, we chose another measure of physiological response that is effective at capturing task-related and cue-related differences in responding in both cognitive tasks and deception tasks.

Pupil Response Measures

Pupillometry, a pupil response measure, is the measure of change in pupil diameter as a function of task demands. It is a noninvasive measure of autonomic nervous system activity, and an effective measure of both cognitive activity and the differences between truthful and dishonest responding experimentally. Additionally, it is capable of capturing changes in one's attentional state when they are preparing to make a behavioral response. Generally, the change in pupil diameter from a baseline measurement to a post-stimulus temporal location is used, and differences in this measurement between opposing stimuli presentation or task demands are thought to reflect the effect of the variable change on cognitive processing. Change in pupil diameter has been shown to correspond to cognitive effort and task difficulty, both in tasks assessing executive functions, and when being questioned about one's involvement in a mock crime.

Pupil response measures can reliably index cognitive effort (Hess & Polt, 1964; Peavler, 1974), as they are sensitive to alterations in task difficulty (Heitz et al., 2008; Kahneman & Beatty, 1966). Pupillometry is considered a noninvasive measure of arousal and locus coeruleus norepinephrine (LC-NE) system functioning (Ashton-Jones & Cohen, 2005). The LC operates through two modes of NE firing occurring throughout the neocortex. When external stimuli are particularly demanding of attention, NE is released in short, phasic bursts in anticipation of, and during responding to, goal demands, representing a state of exploitation of stimuli within one's environment (Unsworth & Robison, 2017). When external stimuli are not demanding of attention, resting baseline tonic NE activity represents a state of exploration for the individual (Ashton-Jones & Cohen, 2005). Differences in tonic activity have been shown to be associated with individual differences in cognitive ability (Van der Meer et al., 2010).

Pupil Response Measures, Task Difficulty, and Cognitive Effort

In an early test of working memory, Kahneman and Beatty (1966) demonstrated a linear increase in pupil size with the addition of items in a forced-recall task, and during real-time, pre-instructed transformation of selected items. The harder the tasks became in this study, the larger participant's pupils dilated, suggesting that pupils increase when tasks become more cognitively demanding. More recently, Heitz et al. (2008) showed a similar positive linear trend between pupil response in high and low WMC participants and set size (i.e., the number of items to be remembered) in the RSPAN task across increasing levels of incentive. This means that individual differences in WMC should be associated with differential changes in pupil size across various tasks despite any external motivational incentives offered. Rondeel et al. (2015) also demonstrated a positive correlation between pupil diameter and Stroop task performance as a function of task difficulty, in that they observed larger pupil diameter for incongruent relative to congruent trials. Van der Meer et al. (2010) showed that relative to individuals average in fluid intelligence, another executive function defines as the general ability to reason in novel situations (Draheim et al., 2022), individuals high in fluid intelligence produced larger peak pupil diameters when performing a harder geometric analogy task, but similar peak pupil diameters when performing an easier forced-choice reaction time task. The authors reasoned that the larger change in pupil size observed for the high fluid intelligence group suggested this group allocated resources more efficiently when they were necessary for performance in the harder of the two tasks. Findings from these last three studies suggest that larger increases in pupil diameter are associated with better executive function task performance. Common across all studies mentioned is that pupil response demonstrably increases when performing tasks requiring better cognitive ability and control of attention.

Pupil Response Measures and Measures of Deception

Pupil response measures are also used to assess the cognitive effort involved when lying. The paradigms using pupil response as a primary dependent measure vary between tasks in which participants must commit a mock crime or must simply answer questions that are emotionally neutral. When used as a dependent measure in various deception detection paradigms, pupil response measures have high predictive validity and are effective at discriminating truthful from dishonest responses and participants who are guilty or innocent of mock-crimes.

Dionisio et al. (2001) used the differentiation-of-deception paradigm (Furedy et al., 1988) which asked emotionally neutral semantic and episodic questions to isolate cognitive aspects of deception, and measured changes in pupil diameter observed during truthful and dishonest responding. Participants were asked questions while a “T” for truth, or “L” for lie, appeared on the computer screen in front of them, instructing them on how to answer the question. Once the question was presented, they were instructed to abstain from answering for a 4,000 ms “critical period”. This critical period was used to measure pupil response between truthful and dishonest trials in anticipation of responding. They found significantly smaller changes in pupil diameter for both trial types during question presentation relative to the critical and response periods, and a significant increase in pupil diameter for lie trials relative to truth trials in both the critical period and response period irrespective of whether the question was of semantic or episodic content. This study's paradigm and materials were the closest conceptually to the current study.

Other studies using pupil response measures to classify deceptive responses used mock-crime scenarios to simulate real-world emotional reactions that may be experienced by "suspects." Findings from these studies show that the maximum amplitude in pupil diameter reached following questions asked about these mock-crimes is largest for participants who committed them and are answering questioning dishonestly (Bradley & Janisse, 1981; Webb et al., 2009), and are larger when lying to questions that are specific to the mock-crime committed by the participant when multiple mock-crimes are being investigated (Cook et al., 2012). In addition to a larger increase in pupils for participants guilty of mock-crimes who are lying about their crime-involvement, the increase in pupil diameter is shown to be more rapid and steeper for participants lying about involvement in mock-crimes (Lubow & Fein, 1996, Experiment 2), and for participants lying about stimuli previously presented in a face-recognition paradigm (Seymour et al., 2013). These last two findings suggest that both the arousal involved in lying about mock-crime involvement and the saliency of stimuli that participants previously viewed as part of the mock-crime scenarios or experimental paradigms contributes to this larger and steeper increase in pupil size observed when responding deceptively.

Pupil response measures are shown to effectively assess differences in responding as a function of task difficulty, and differences between truthful and dishonest responding. However, all studies mentioned measured what are called task-evoked pupillary responses, meaning the changes in pupil size was observed once stimuli were presented or questions were asked. In the current study, we are interested in cue-evoked pupillary responses (CEPRs) that are taken once a pre-stimulus/question prompt is presented to assess differences in participant's attentional states when anticipating giving a truth or lie response. This is a less explored measure of pupil response, although some previous studies have captured changes in this pre-stimulus interval that reflect participant's anticipation of making responses that differ based on their perceived difficulty.

Pupil Response Measures When Preparing to Respond

There are a few examples of studies who measured CEPR differences when cued to make upcoming responses. Kahneman and Beatty (1967) had participants discriminate auditory comparison tones from a standard tone, with a fixed 4 s gap between the standard and comparison tones. Participant's pupils dilated for the first couple of seconds following the presentation of the standard tone, constricted for most of the remainder of the fixation interval, and then dilated just before the onset of the comparison tone. This was possibly the first study to demonstrate orientation of attention toward a cued auditory stimulus, followed by tonic exploration in anticipation of a behavioral response, and finally an increase in pupil diameter immediately preceding the auditory comparison tone indicating an increase in cognitive effort.

Later, Kahneman and Wright (1971) measured participant's pupils while they partially or fully recalled lists of presented items while manipulating the interval between the end of a presented list and the beginning of the recall period. Preceding item presentation, participants were given a cued announcement as to which recall condition they would perform following the last list item. Pupil measurements began approximately 500 ms following this announcement. During the interval between the announcement and the first list item, participant's pupils dilated much more when told they would have to recall the full list of items, and when told that the interval between the list presentation and the recall period was shorter, indicating increased cognitive preparedness in anticipation of these more difficult and demanding trials.

More recently, McCloy et al. (2016, Experiment 2) had participants perform an auditory attention switching task in which a prompt was delivered via a recorded male or female voice that indicated which speaker's voice to attend to first during trials, and which upcoming trial type to expect. After the prompt, both a recorded female and male voice concurrently presented four letters, with a variable gap between the second and third letter presentation, representing the period when participants either had to continue attending to the same gendered voice as they had during the first two letters (no-switch trial), or attend to the speaker's voice opposite the gender attended to during the first two letters (switch trial). Using a deconvolution technique (Weirda & Colleagues, 2012) to precisely measures pupil dynamics throughout trials, they demonstrated a significant increase in pupil diameter following the prompt when a switch trial was announced relative to when a no-switch trial was announced. Across these studies measuring CEPRs in a fixation interval preceding stimulus onset individuals tended to exert more cognitive effort, as indicated by increased pupil dilation, in preparation of difficult relative to easier response types.

Hood et al. (2022). Pupil response measures are also shown to assess the efficiency with which participants exert cognitive effort in periods of attentional preparedness (Hood et al., 2022). More variability in pupil size observed throughout trials in various tasks is driven by low (hypoarousal), high (hyperarousal), or dysregulated baseline tonic activity of the LC-NE system (Robison & Brewer, 2020), producing lapses in attention associated with individuals low in WMC (Unsworth & Robison, 2017). Hood et al. (2022) captured individual differences in the efficiency of controlled attention in an anticipatory interval preceding stimulus presentation by having participants perform the antisaccade task after measuring their WMC using the automated operation span task (Unsworth et al., 2005). In the antisaccade task, participants quickly look to either the same (prosaccade) or opposite (antisaccade) side of a computer screen as a cue (a "*" symbol) presented for 300 ms to view and report a stimulus (the letter "O" or "Q") presented for 100 ms. Their performance in this task is assessed by their ability to accurately report the rapidly presented stimulus. The version of the antisaccade task in Hood et al. (2022) also presented participants with a visual task indicator shown at the beginning of each trial reading either "Toward" or "Away" alerting them to which side of the screen the upcoming stimulus would appear in relation to the cue. Replicating previous study's findings (Hutchison et al., 2020; Wang et al., 2015), Hood et al. (2022) showed a greater increase in pupil size preceding antisaccade relative to prosaccade trials, which is consistent with findings from other studies (Kahneman and Wright, 1971; McCloy et al., 2016, Experiment 2) where participants exerted more anticipatory cognitive effort preceding trials perceived as more relative to less difficult.

Additionally, Engle (2018) posits that antisaccade trials require AC, as they require participants to override the prepotent and automatic response of looking in the direction of a flashing or moving stimulus in one's environment. Indeed, Hood et al. (2022) provided support for this notion. When analyzing CEPR activity between participants of "poor", "middle", and "good" performance based on the number of errors committed on antisaccade trials, and between participants "low", "middle", and "high" based on their WMC scores, a similar pattern of poor performer/low WMC participants exerting increased cognitive effort early on, and throughout, the fixation interval was observed. Also, the better performers and those high in WMC tended to show a more flattened and reduced CEPR pattern early in the fixation interval, with a significant increase in pupil size immediately preceding the presentation of the cue and stimulus during antisaccade trials. This not only suggests more efficient exertion of attentional effort needed for performance, but that this efficiency was exclusively observed for high WMC participants, meaning it was driven by better AC (Engle, 2018). This is further supported by the finding of decreased CEPR variability for participants high in WMC (Hood et al., 2022), as higher variability in pupil response is associated with less efficient exertion of cognitive effort (Robison & Brewer, 2020).

Hood et al. (2022) provided the most extensive investigation into the changes in pupil size occurring before task stimuli are presented, but after participants are aware of the task difficulty in upcoming trials. Differences in task difficulty in this version of the antisaccade task can be argued as representing the difficulty in antisaccade responses that require AC, and prosaccade responses that simply require individuals to follow their natural inclination to orient their focus in the direction of flashing stimuli (Engle, 2018). Similarly, it is theorized that deception is generally a controlled, and therefore more difficult, response type than telling the truth, which is a more automatic, natural, and subsequently easier task to perform (Walczyk et al., 2014). These parallels of the automatic and controlled processes between prosaccade/antisaccade and truthful/deceptive responses, suggest potential differences in CEPR patterns that may precede answering questioning in an experimental deception paradigm as well.

Current Study

Using the Hood et al. (2022) paradigm as a template, the purpose of the current study was to investigate the differences in AC as indicated by differential pupil response patterns observed in an interval between the presentation of a prompt alerting participants on how to answer upcoming questions, and the question presentations that followed, using a paradigm instructing participants to give truthful and dishonest responses. In this way, we are isolating and measuring the decision component of the ADCAT theory (Walczyk et al., 2014), to determine if the cognitive demand of lying is apparent not only when individuals are giving dishonest responses, but also when they are preparing to give dishonest responses. WMC was measured in an attempt to replicate findings from Hood et al. (2022), and because high WMC participants from previous studies were shown to have superior lying ability (Maldonado et al., 2018; Lo & Tseng et al., 2018). AC was measured as it is theorized to be necessary for WMC (Engle, 2002, 2018), and because previous studies have demonstrated that participants high in inhibition, a conceptually similar executive function, were also shown to be superior liars (Battista et al., 2021; Visu-Petra et al., 2012, 2014). RTs and errors committed when responding to questions were used in conjunction with the pupil response measures taken prior to questions being asked to determine if they are predicted by the attentional state captured in the fixation interval. Following from the findings in Hood et al. (2022), the following are hypothesized.

- H_1: Cue-evoked pupillary responses will be larger in a pattern of dilation in anticipation of lie trials relative to truth trials.

This hypothesis follows from Hood et al. (2022), Hutchison et al. (2020), and Wang et al. (2015), who demonstrated this when participants were preparing to respond to the harder antisaccade trials relative to the easier prosaccade trials in the antisaccade task. This hypothesis is intended to support the notion that lying is more cognitively demanding than telling the truth, before either response is carried out, in anticipation of making a response. If CEPRs are not significantly increased on lie trials, it may suggest that the cognitive demand is only apparent once a response is constructed and delivered, meaning the decision component alone does not contribute greatly to any additional cognitive demand involved in lying. If CEPRs are larger for truth trials, it may suggest that either the questioning in this paradigm, or telling the truth itself is preceded by more attentional effort than telling a lie, meaning that it is perceived as more demanding.

- H_2: Attentional control and working memory capacity will be negatively correlated with the proportion of errors committed (termed "Compliance" in this study).

This hypothesis follows from findings from studies that mentioned high WMC or inhibition as being associated with a lower proportion of errors committed (Battista et al., 2021; Maldonado et al., 2018). It is also consistent with the finding that attentional lapses (Unsworth & Robison, 2017) and tonic disengagement of the LC-NE system (Ashton-Jones & Cohen, 2005) tend to be accompanied by higher rates of error commission. Not finding support for this hypothesis may indicate that the task is too easy, and so all participants were committing a similar number of errors.

- H_3: Attentional control and working memory capacity will be positively correlated with cue-evoked pupillary responses in the final seconds of the fixation interval preceding lie trials.

This hypothesis is specifically in relation to what was found in Hood et al. (2022). Participants high in WMC exerted effort late in the fixation interval just before a response was needed, indicating they are better at exerting cognitive effort when it is necessary. Van der Meer et al. (2010) similarly found that participants high relative to participants that were average in fluid intelligence exerted more effort for a harder geometric analogy task than for an easier forced-choice recall task, as indicated by increased pupil dilation for the harder task. If supported, this hypothesis suggests this finding as robust across tasks of varying demands. If a different CEPR pattern is found for high WMC and AC participants, it suggests that lying, or the paradigm used, may involve different preparatory processes than the other cognitive tasks where it was observed.

- H_4: Cue-evoked pupillary response variability will be positively correlated with the proportion of errors committed.

This final hypothesis is like the second hypothesis, in that higher pupil variability observed in the fixation interval across trials suggests disengagement from the task and attentional lapses that often are accompanied by error commission. Significant negative correlations between pupil variability and saccade accuracy demonstrated in Hood et al. (2022) provide precedent for this prediction. If it is not supported, it again may suggest the task as being too easy, and so high AC and WMC are not as necessary for optimal performance.

CHAPTER TWO

METHODOLOGY

Methods

Participants

Participants were recruited via an online SONA system subject pool as part of an introductory psychology course research requirement. Participants who did not have normal or corrected-to-normal vision, were deaf, and who were not native English speakers were not able to participate. The sample size was projected using findings from Hood et al. (2022) and Maldonado et al. (2018). First, Hood et al. found an effect of $n_p^2 = .181$ for trial type, indicating larger pupil diameter when preparing to make an antisaccade than a prosaccade response. To find a similar-sized effect of response type in the current study would require a necessary sample of 14 participants. Also, Hood et al. found a Pearson r correlation coefficient between antisaccade accuracy and WMC of .323 and Maldonado et al. found a correlation between WMC and detectability of -.287. To achieve a power of .90, necessary samples of 92 and 123 participants are needed for the higher and lower correlations, respectively. Therefore, the goal was to run 120 participants. A total of 149 individuals participated.

After data collection, we removed data from 26 participants due to technical issues with the eye tracker causing missing pupil data., and 1 additional participant who was missing RSPAN data, resulting in usable data from 122 participants. Participants were on average 19.11 years old (range = 17-32 years old), with a gender distribution of 68% females and 32% males.

Design

Tasks involved in the methodology were completed by the entire participant sample. The study used a 2 (Trial Type: Truth or Lie) x 5 (Time) within subjects design with AC and WMC as between subject variables entered as continuous covariates. Pupil diameter and errors were examined as a function of both Trial Type and Time. Participants were tested individually in a laboratory session lasting approximately 1 hour.

Apparatus

The same equipment was used for this study as was used in Hood et al. (2022) and Hutchison et al. (2020). Specifically, E-Studio E-Prime software from Psychology Software Tools (Version 2.0.8.90) was used to program and present the fixation and auditory stimuli and a Panasonic CF-50 ToughBook laptop, with a Mobile Intel Pentium 4-M 2.00 GHz processor, 768 MB of RAM, and an AT Mobility Radeon 7500 Display Adapter was used to run the experiment. Task stimuli was presented on a 17-inch NEC Multisync LCD 1760v monitor, with 1,024 x 768 screen resolution and a 60-Hz refresh rate.

The eye-tracker used to measure pupil response is a contact-free, remote-controlled infrared eye camera (RED) with automatic gaze and head trackers designed by SensoMotoric Instruments (SMI). This device allowed participants to view the computer monitor while listening for auditorily-delivered stimuli without the use of a chinrest. The tracker has binocular temporal resolution of 120 Hz, with spatial resolution of 0.03° and gaze position accuracy of 0.4°. Participants sat approximately 60 cm from the RED camera positioned directly under the computer monitor presenting task stimuli. An RS232 USB serial port on the Panasonic

ToughBook laptop allowed the SMI RED tracking software to communicate with the E-Prime software that ran the deception task.

Procedures

The paradigm is similar to the one used by Hood et al. (2022), but modified to accommodate differences between the tasks. First, participants filled out an autobiographical questionnaire used in the deception task portion of the procedure, and then they performed a cognitive test battery comprised of WMC and AC tasks. Two complex span tasks measuring WMC were administered, followed by three novel Squared tasks used to measure AC. The purpose of the WMC tasks is twofold: to replicate the procedures of Hood et al. (2022) by using a variation of the AOSPAN task, and because higher WMC individuals have been shown to be better at evading detection (Maldonado et al., 2018), suggesting they are generally more convincing liars. The three AC tasks are used because AC is crucial for the maintenance of goal-relevant information and suppression of goal-irrelevant information (Burgoyne & Engle, 2020), because changes in pupil diameter are thought to correspond to variations in attentional mechanisms (Unsworth & Robison, 2017), and because they represent reliable and valid measures that each take approximately three minutes to administer (Burgoyne et al., 2022). Following the cognitive test battery, participants performed the main deception task while CEPRs were recorded between the prompt and question onset. Regarding pupil measurements, all tasks took place in the same windowless room with 680 lux of illuminance from overhead fluorescent lights.

Cognitive Test Battery. In the interest of time, the shortened operation span (OSPAN; Foster et al., 2015) and reading span (RSPAN; Oswald et al., 2015) tasks were administered to assess WMC. The shortened OSPAN presents participants with simple math problems (e.g., Is (4 + 2) - 1 = 5?) and instructs them to indicate via mouse click whether the answer presented is "True" (correct) or "False" (incorrect). Following each math problem, a letter is presented to retain in memory. After a variable number of sets of math problem/letter pairs, a prompt screen appears for participants to recall the letters in their correctly presented order via mouse click. The OSPAN score is the total number of letters recognized in their correct order, with a minimum score of 0 and a maximum score of 37 for this version.

The shortened RSPAN task presents participants with simple sentences (e.g., "Paul is afraid of heights and refuses to fly on a plane") and instructs them to indicate whether the sentence is sensible by responding "True" (sensible) or "False" (nonsensical) via mouse click. Following each sentence, a letter is presented to retain in memory. The RSPAN consists of between 4-6 sets of sentence/letter pairs before participants are instructed to recall the letters in their correctly presented order via mouse click. Their RSPAN score is the total number of letters recalled in the correct order, with a minimum score of 0 and a maximum score of 30 for this version.

The Stroop-Squared, Flanker-Squared, and Simon-Squared tasks (Burgoyne et al., 2022) are used to assess AC. These tasks take three minutes or less to administer and demonstrate excellent internal consistency (avg = .95) and good test-retest reliability (avg r = .67). They are intercorrelated with each other (avg r = .50), and when combined into a single latent factor, they have been shown to be highly correlated (avg r = .80) with another latent AC factor consisting of the selective visual arrays task (Luck & Vogel, 1997), the sustained attention to cue task (SACT; Draheim et al., 2021), and the antisaccade task (Hutchison, 2007). Each task provides an additional layer of conflict to their respective traditional measures, with four possible trial types: fully congruent (both the stimulus and response options have no conflicting qualities), fully incongruent (both the stimulus and response options have conflicting qualities), stimulus congruent/response options incongruent (the stimulus has no conflicting qualities; the response options have conflicting qualities), and stimulus incongruent/response options congruent (the stimulus has conflicting qualities; the response options have no conflicting qualities). Each task is scored by giving one point for each correct response and deducting one point for each incorrect response, with the final tally following the test phase representing the participant's total score. Performance feedback is provided on each trial. Scores and time remaining are visible throughout the tasks.

Stroop-Squared, like the traditional Stroop task, presents participants with words whose meaning may or may not be congruent with the color in which they are written. In this task, participants are additionally presented with two on-screen response options presented below the stimulus, and are instructed to choose the option sharing the meaning with the presented color of the stimulus. For example, if the stimulus is the word "Red" written in blue, and the response options are "Red" written in red and "Blue" written in blue (i.e., stimulus incongruent/response options congruent trial type), the correct response is the blue-colored "Blue" response option even though it conflicts with the meaning of the stimulus. In other words, the response option should be the word whose meaning describes the color of the stimulus. For the Flanker-Squared task, the stimulus and response options are flanker items consisting of 5 arrows (e.g., "<<><<"). Participants are instructed to choose the response option with the central arrow pointing in the same direction as the flanking arrows of the stimulus. So, if the previous example given represented the stimulus, a correct response option could be “>><>>” (i.e., a fully incongruent trial type). For the Simon-Squared task, the stimulus is an arrow symbol, and the response options are the words “Left” and “Right” appearing below the stimulus on either side of the screen. The arrow can point in either direction indicated by the response options and can appear on either side of the screen above the response options, so task success depends on attention being paid to the direction of the arrow and the meaning of the response option. Each task consists of a single demonstration trial that is fully congruent between the stimulus and response options, and instructions on how to perform the task. This is followed by a 30-second practice phase, and finally, the 90-second test phase.

Deception Task. The cognitive test battery allowed for a delay and served to distract participants between the time they filled out the initial questionnaire (shown in the appendix) and when they performed the deception task, eliminating the possibility of preparing and rehearsing deceitful responses in advance. The 40-item questionnaire completed before the cognitive test battery was a modified version of the questionnaire used in Maldonado et al. (2018). This questionnaire asked emotionally-neutral questions of autobiographical content (e.g., “What is your favorite color?”) to control for differential significance of question content often observed when using the comparison question test and the concealed information test paradigms (Furedy et al., 1988). The questions required short 1–2-word answers to control for the complexity of response, and consistency in timing across responses. The questions were controlled for word length and number of syllables, and were evenly split between factual and preference-based content. This final detail was an incidental byproduct of the original questionnaire devised by Maldonado et al. (2018), but like previous paradigms (e.g., Dionisio et al., 2001 assessing differences in responding between questions that were episodic or semantic in nature), it allows for exploratory assessment of the discrete or open-ended nature of autobiographical question content, to determine any differences in responding between factual questions (e.g., "Where were you born?") and preference-based questions ("What is your favorite TV show?").

The sequence of the deception task was identical to the sequence of the antisaccade task used in Hood et al. (2022), without the use of measures that are irrelevant to the current experiment (e.g., thought probes to measure instances of mind-wandering), and modified to accommodate the current task. Each trial began with a prompt alerting participants to the upcoming trial type. The word "Truth" or "Lie" was delivered auditorily for ~500 ms using recordings of a male voice while participants focused their gaze on a fixation cross centrally located on the computer screen in front of them. A 5,000 ms fixation interval began 1,000 ms following the prompt, at which time CEPRs were measured. After the fixation interval, a question was delivered auditorily using the same male voice that delivered the prompt. A 440 Hz beeping noise immediately followed the question presentation for 200 ms, and the microphone was triggered for participants to respond immediately following the beep. This post-question beep served to alert participants to when they could answer and to prevent them from attempting to answer the question before it was fully presented, as all the questions differed slightly in their presentation duration. Delivering both the prompt and question auditorily ensured any variation in pupil response across trials was attributable to only one presentation sensory modality. Following the beep, participants were instructed to verbally answer the question according to the prompt preceding the fixation interval as quickly and convincingly as possible while their verbal response RTs were recorded. Once the question was answered and the RT was recorded, there was a 5,000 ms ITI before the next trial began. The fixation cross appeared on-screen throughout blocks of questions. Between each block, instruction screens visually reminded participant to answer the questions as quickly and convincingly as possible. Participants completed 4 blocks of questions with 10 questions per block, with each block containing an equal number of randomly dispersed truth and lie response prompts. There were two versions of this task, with every other participant given either version to ensure an equal number of answers for each question. Response type was counterbalanced between the two versions of the task across participants, so that questions were answered equally as truth and lie responses across subjects. Once the task was completed, participants were debriefed and thanked for their participation.

CHAPTER THREE

RESULTS

Results

The data from the cognitive measures assessing AC and WMC were first examined. Then, overall effects and any interactions between participant compliance and the cognitive constructs were examined using separate ANCOVA analyses with AC and WMC entered as covariates. Next, pupil diameter analyses of CEPRs, and their relation to AC, WMC, and compliance were performed. Finally, multiple regression analyses were conducted to identify any potential unique contributions of WMC, AC, CEPRs, and CEPR variability in predicting compliance, as well as unique contributions of WMC and AC in predicting CEPR variability. Due to equipment failure of the microphone causing a loss of over 80% of participants with at least 75% of trials with RTs recorded, we excluded this dependent measure from the final analyses. In all analyses, a two-tailed *p*-value of .05 is used as the criterion for significance, and all effect sizes are reported as partial eta squared (n_p^2). Means and standard error bars are presented in all the figures.

Cognitive Measures

First, a composite WMC variable was computed by averaging the standardized scores of the RSPAN and OSPAN tasks. Then, the three tasks used to assess AC were entered into an unrotated principal components analysis to be predicted by a single AC component. The single AC component accounted for 64.77% of the variance. Bivariate correlational analysis was run for all the cognitive measures, yielding significant correlations between all pairs of tasks and the composite variables with exception of the correlation between the SIMON Squared and RSPAN tasks. Correlations between the cognitive tasks and composite variables are shown in Table 1.

Table 1: The intercorrelations between the cognitive measures. Values with two stars are significant at the p < .01 level.

Measure	1	2	3	4	5	6	7
1. RSPAN	-						
2. OSPAN	.398**	-					
3. Stroop Squared	.167**	.115**	-				
4. Flanker Squared	.211**	.150**	.463**	-			
5. SIMON Squared	.027	.158**	.432**	.518**	-		
6. WMC	.836**	.836**	.169**	.216**	.111**	-	
7. AC	.168**	.176**	.777**	.827**	.810**	.205**	-

Behavioral Results

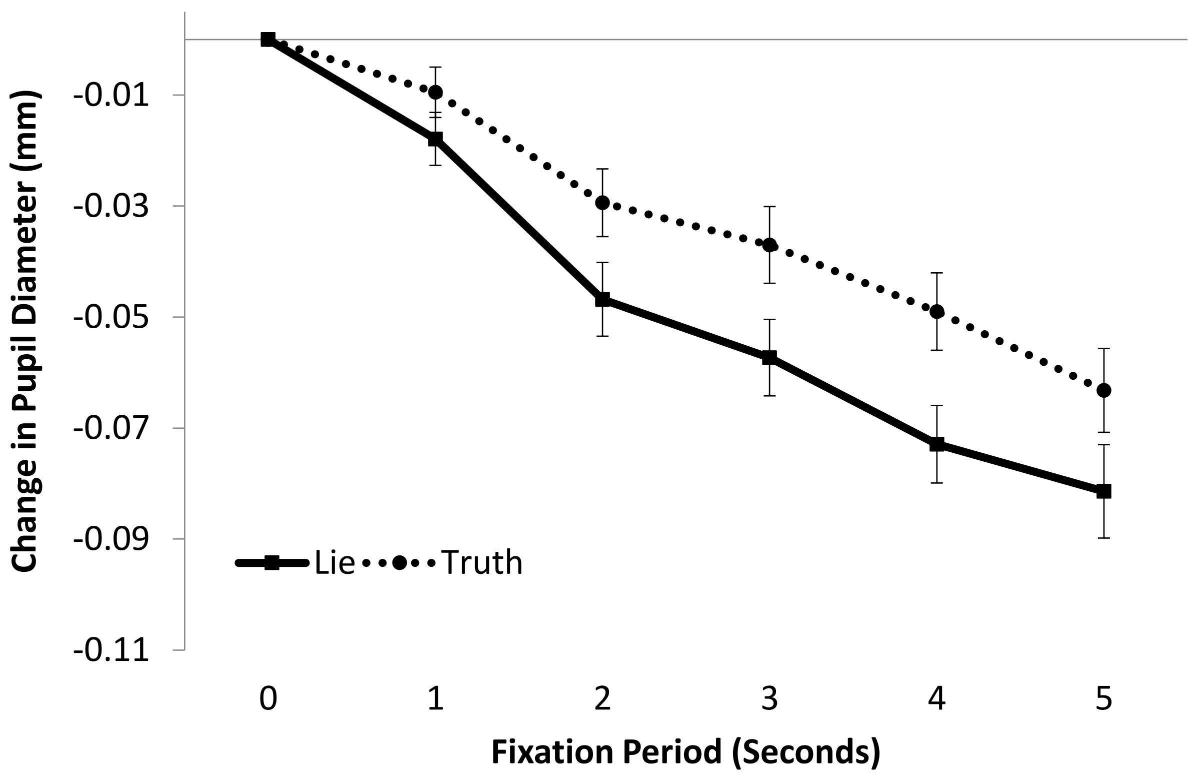
Response Compliance. Numerically, participants committed more errors on truth trials (*M* = .05, *SE* = .06) than on lie trials (*M* = .04, *SE* = .06), although the difference did not reach significance, $t(121) = 1.856$, $p = .066$. When AC and WMC were entered as covariates, there were no main effects of response type or interactions with either cognitive construct for errors (both *p*'s > .79). Neither WMC nor AC correlated with errors observed for either response type.

Pupil Diameter Analyses

Cue-Evoked Pupillary Response (CEPR). A 50 ms baseline interval was used to derive pupil diameter changes over the 5,000 ms fixation interval. This differed from Hood et al. (2022) who used a 30 ms baseline interval. However, 50 ms captured the most baseline scores while not overlapping with any of the mean measurements for the first bin. During the 50 ms baseline period, pupil diameter was .018 ± .029 (± = 95% confidence interval) larger for lie trials (*M* = 3.693 mm) than for truth trials (*M* = 3.664 mm), which was a significant difference between trial types at baseline, $t(122) = 3.248$, $p = .002$. If lie trials, being the more complex trials relative to truth trials, are more similar to antisaccade trials used in the paradigms that inspired this study, these results differ from the previous findings in both Hood et al. (2022) and Hutchison et al. (2020), in that they observed a larger baseline pupil for the easier prosaccade trials.

As in the previous reference studies, the data was centered on baseline pupil diameter to clearly observe the phasic pupil changes during the fixation period. A 2 (Trial Type) x 5 (Time) ANOVA was performed to examine the time course of CEPRs during the 5,000 ms fixation interval, using CEPRs that preceded accurate trials only. The Greenhouse-Geisser correction was used for all reported statistics in which there was a violation of sphericity. There was a main effect of Trial Type, $F(1, 121) = 7.324$, $p = .008$, $n_p^2 = .057$, with larger CEPRs overall for lie responses than truth responses, and a main effect of Time, $F(1.895, 229.327) = 47.517$, $p < .001$, $n_p^2 = .282$, with pupil diameter significantly decreasing from baseline at each second in the fixation interval as depicted in Figure 1. The Trial Type x Time interaction did not reach significance ($p = .104$); however, suggesting this decrease occurred similarly for either trial type. This pattern did not replicate the findings from Hood et al. (2022), in that instead of dilating, pupils constricted across the fixation interval. The pattern of constriction more closely resembles findings from Hutchison et al. (2020). Although, they observed greater constriction for the easier prosaccade trials, and pupil constriction was greater in the harder lie trials in the current study.

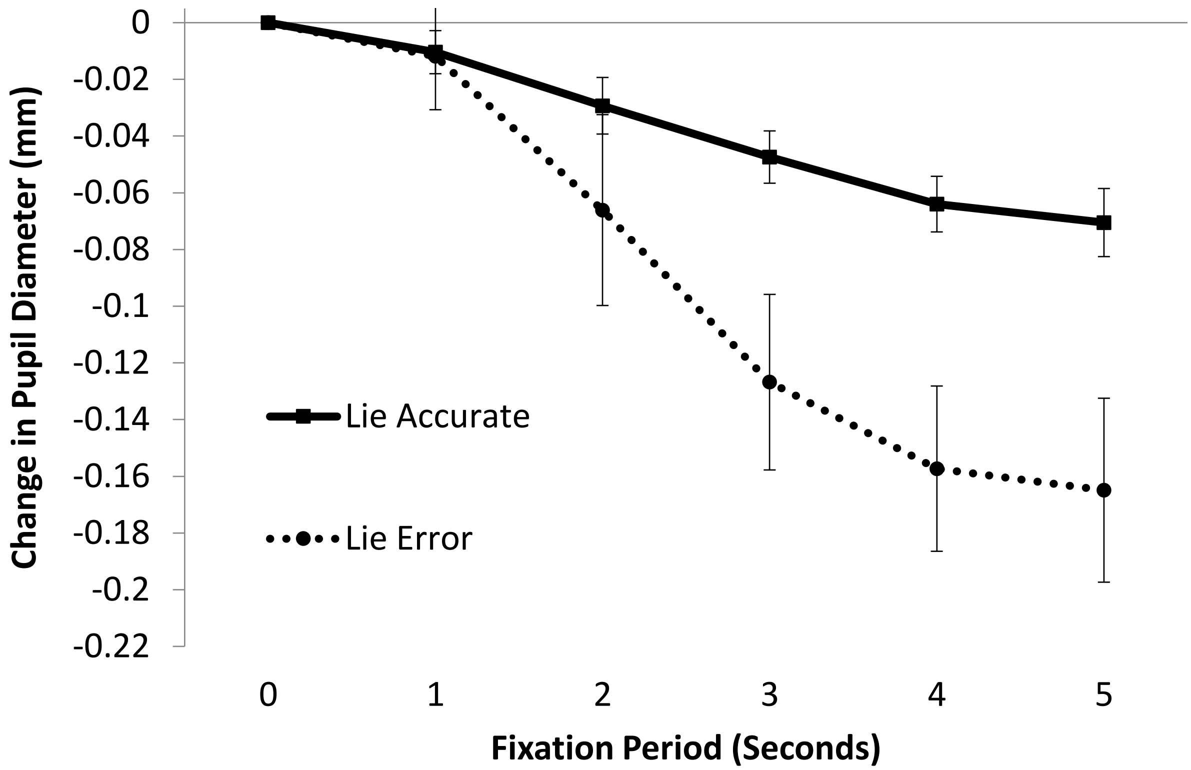
Figure 1: Cue-Evoked Pupil Response differences across the fixation interval between truth and lie responses. The error bars reflect the standard error for paired-sample difference across time periods.



CEPR and Compliance. CEPR patterns were analyzed in relation to question compliance, with separate analyses performed for each trial type. Due to ceiling effects that were observed for both trial types, an exploratory analysis was performed on the changes in pupil diameter as a function of compliance for 47 and 70 participants for lie and truth trials, respectively.

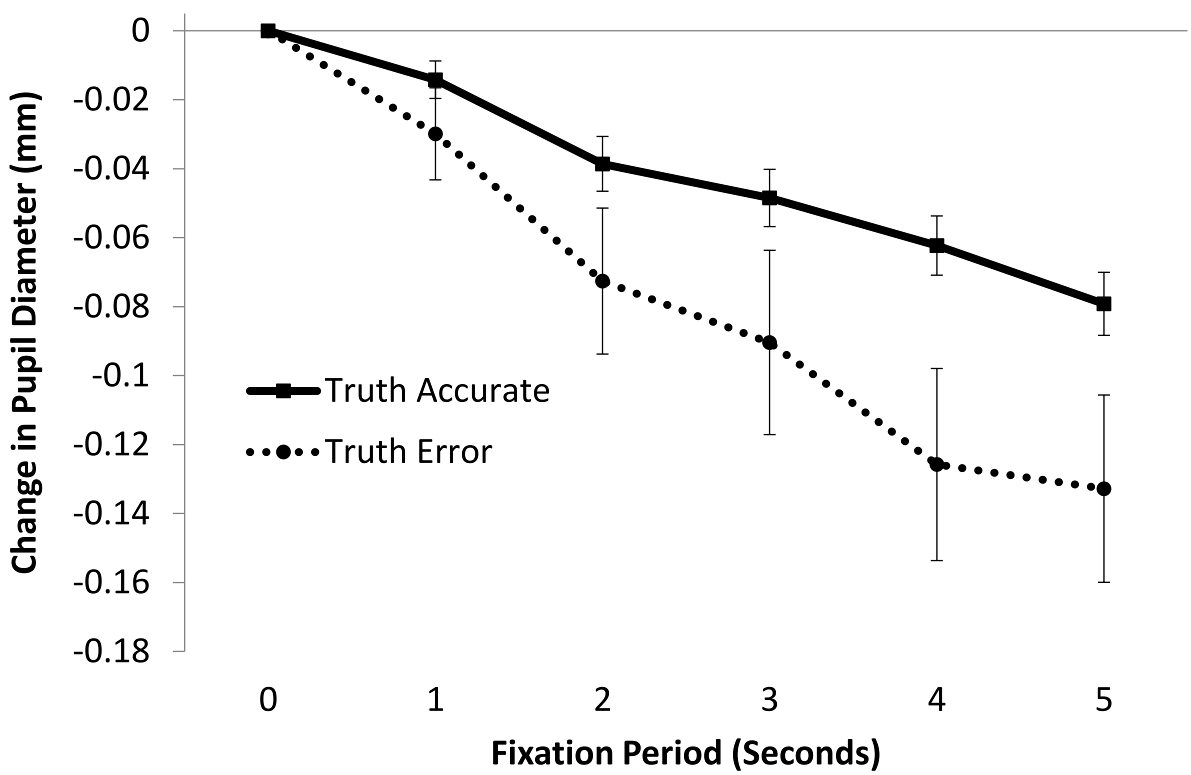
Separate 2 (Compliance) x 5 (Time) ANOVAs were used to examine CEPRs preceding accurate and erroneous responses for both trial types. CEPR patterns as a function of Compliance are shown in Figures 2 and 3 for lie and truth trials, respectively. For lies, there was a main effect of Compliance, $F(1, 46) = 6.753$, $p = .013$, $n_p^2 = .128$, and a main effect of Time, F(2.365, 108.773) = 17.243, $p < .001$, $n_p^2 = .273$, which were both qualified by a significant Compliance x Time interaction, $F(2.356, 108.388) = 3.696$, $p = .022$, $n_p^2 = .074$. Participant's pupils decreased in size at the beginning of trials, regardless of whether their upcoming response was accurate or erroneous. However, their pupils decreased more rapidly for non-compliant (error) trials than for compliant (accurate) trials over the first several seconds of the fixation interval and then stopped decreasing during the fourth and fifth seconds. For accurate trials, their pupils steadily, but less rapidly, decreased throughout the fixation interval. The interaction was further examined through separate ANOVAs performed on the early CEPRs (bins 0-3) and late CEPRs (bins 4-5) between accurate and erroneous trials. There was a significant Compliance x Time interaction for the analysis examining early CEPRs, $F(2, 92) = 3.649$, $p = .030$, $n_p^2 = .073$, with the change in pupil diameter significantly larger for error trials ($M = -.127$, $SE = .031$) than for accurate trials ($M = -.047$, $SE = .009$) at the third second of the fixation interval. The Compliance x Time interaction was not significant for late CEPRs, as there was only a main effect observed for Compliance for lie trials during this period, $F(1, 46) = 9.289$, $p = .004$, $n_p^2 = .168$. This main effect indicated that CEPRs were significantly greater for non-compliant lie trials than for compliant lie trials in the final two seconds of the fixation interval.

Figure 2: Cue-Evoked Pupil Response for accurate and erroneous lie trials. Error bars reflect the standard error for paired-sample difference across time periods.



For truth trials there was a main effect of Compliance, $F(1, 69) = 4.825$, $p = .031$, $n_p^2 = .065$, with a larger decrease in pupils for erroneous ($M = -.090$, $SE = .020$) than for accurate trials ($M = -.049$, $SE = .007$), and a main effect of Time, $F(2.353, 162.364) = 16.862$, $p < .001$, $n_p^2 = .196$, with a significant decrease in pupil diameter across the first two seconds of the fixation interval and between seconds 3 and 4. The Compliance x Time interaction did not reach significance for truth trials.

Figure 3: Cue-Evoked Pupil Response for accurate and erroneous truth trials. The error bars reflect the standard error for paired-sample difference across time periods.



During the 50 ms baseline period, pupil diameter was .085 ± .050 mm (± = 95% confidence interval) larger preceding error trials (M = 3.77 mm) than for accurate trials (M = 3.69 mm). This finding is consistent with Hood et al. (2022) and follows their reasoning that trials in which participants became disengaged from the task are preceded by larger baseline pupils. The robustness of this effect across diverse tasks may suggest a general pattern of larger baseline pupils during initial disengagement from the current task.

Differences in CEPR patterns as a function of participant compliance were assessed for truth and lie trials by allowing the range of individual differences in compliance scores to covary with CEPRs across the fixation interval. Specifically, the proportion of accurate responses was entered as a continuous covariate with Time (5 seconds) in separate ANCOVA analyses for each response type. For lie trials, there was a significant Compliance x Time interaction, $F(1.942, 233.019) = 5.106$, $p = .007$, $n_p^2 = .041$, such that participants lower in compliance had larger decreases in pupil diameter at each second of the fixation interval. For truth trials, there was main effect of Time, $F(2.383, 285.904) = 7.422$, $p < .001$, $n_p^2 = .058$, and a significant Compliance x Time interaction $F(2.383, 285.904) = 5.243$, $p = .003$, $n_p^2 = .042$, with a significant decrease across the first two seconds and the last two seconds of the fixation interval, but not between seconds 2 and 3. These ANCOVA results are similar to the significant interaction found for antisaccade trials, but differ from the lack of an interaction for prosaccade trials found in Hood et al. (2022). Additionally, the current study's findings show an opposing CEPR pattern to Hood et al. (2022). Individual differences in compliance were not correlated with baseline pupil diameter on either lie trials ($r = -.005$, $p = .954$) or truth trials ($r = .024$, $p =.793$).

A median split was performed on the continuous compliance variable to illustrate the significant differences in CEPR patterns as a function of compliance for truth and lie trials that was identified above using the full range of compliance scores. This corresponded to a split at the .00 proportion of errors for lie trials, and at the .05 proportion of errors for truth trials. Because over half of the participants performed at 100% accuracy for lie trials, anyone with a proportion of errors greater than 0 was used in the comparison group. Differences in CEPR patterns between response types for participants above and below the median split are shown in Figures 4 and 5. Pupils decreased more rapidly across the fixation interval preceding erroneous truth trials relative to accurate truth trials.

Figure 4: Cue-Evoked Pupil Response for lie trials between participants high and low in Compliance. The median split yielded samples of *n* = 47 for low compliance and *n* = 75 for high compliance for lie responses. The error bars reflect the standard error for paired-sample difference across time periods.

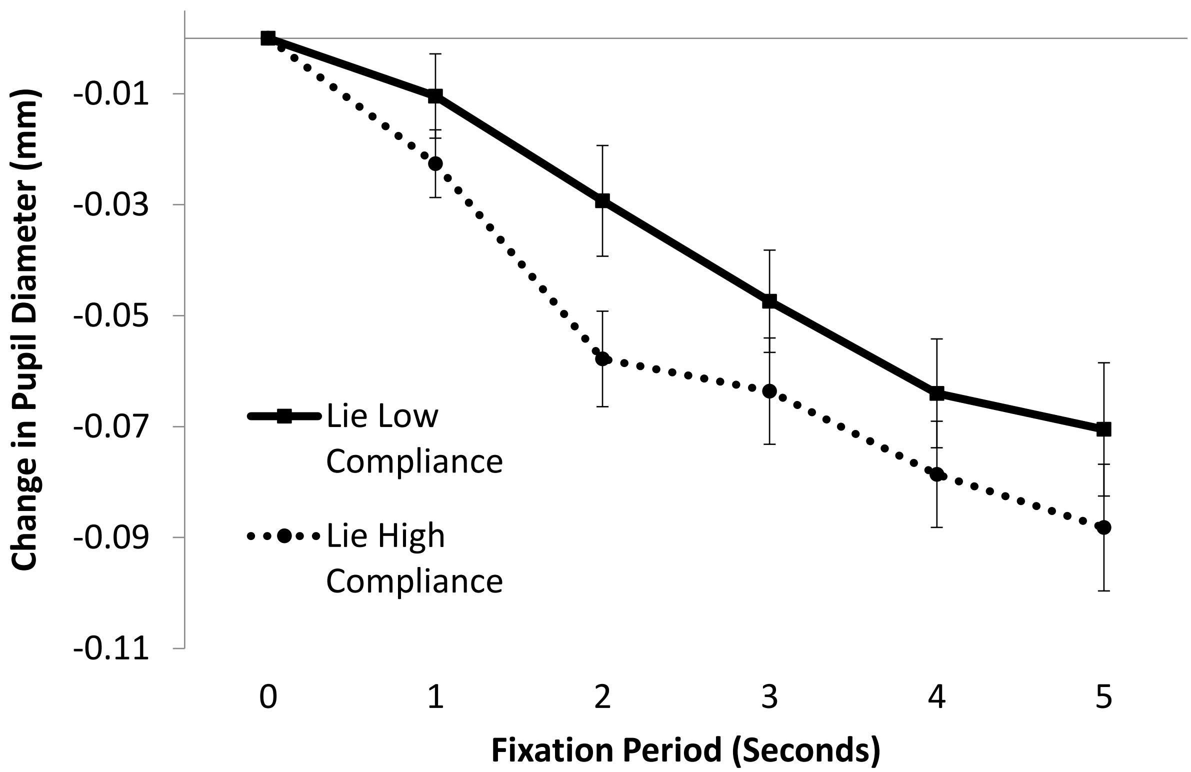
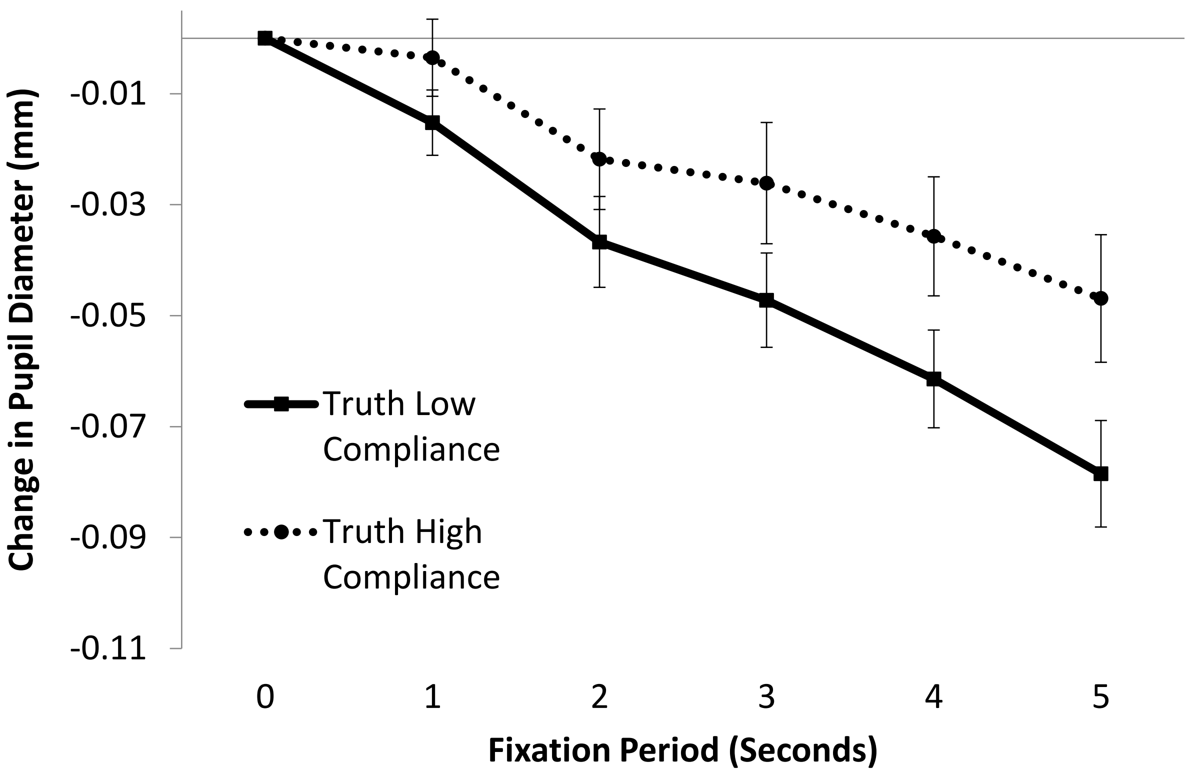


Figure 5: Cue-Evoked Pupil Response for truth trials between participants high and low in Compliance. The median split yielded samples of *n* = 63 for low compliance and *n* = 59 for high compliance for truth responses. The error bars reflect the standard error for paired-sample difference across time periods.



CEPR and Cognitive Ability

CEPR and WMC. Differences in CEPRs as a function of WMC were examined. Pupil diameter during the 50 ms baseline was unrelated to WMC preceding lie trials (r = .019, p = .835) or truth trials (r = .032, p = .726). Differences in CEPRs as a function of response type were examined with WMC enter as a continuous covariate using a 2 (Trial Type) x 5 (Time) x WMC ANCOVA analysis. None of the two-way, or three-way interactions with WMC reached significance (all p's > .238), yielding no conceptual replication of the findings involving WMC in Hood et al. (2022).

CEPR and AC. Differences in CEPRs as a function of AC were examined. Pupil diameter during the 50 ms baseline was unrelated to AC preceding lie trials ($r = .110$, $p = .227$) or truth trials ($r = .113$, $p = .214$). Differences in CEPRs as a function of response type were examined with AC enter as a continuous covariate using a 2 (Trial Type) x 5 (Time) x AC ANCOVA analysis. None of the two-way, or three-way interactions with AC reached significance (all *p*'s > .353), providing no support for one of the main hypotheses.

Predicting Deception Performance and CEPR Variability

Intercorrelations. Prior to using regression analysis to predict individual differences in response compliance, correlational analysis was performed on Compliance, WMC, AC, and CEPR SD (pupil variability). Early CEPRs, calculated as the change in the first 3 seconds of the fixation interval, and late CEPRs, calculated as the change in pupil size in the last 2 seconds of the fixation interval were also examined for each response type. These correlations are shown in Table 2. As shown in Table 2, WMC and AC were correlated, and early CEPRs were highly correlated between the two response types, but there was no correlation observed between early and/or late CEPRs within or between response types. Finally, lie and truth variability were shown to be highly correlated.

Table 2: Correlations between response Compliance, Cue-Evoked Pupil Response, Working Memory Capacity, Attentional Control, and Cue-Evoked Pupil Responses variability. The values with one star are significant at the *p* < .05 level, and the values with two stars are significant at the *p* < .01 level.

	1	2	3	4	5	6	7	8	9	10
1. Lie Compliance	-									
2. Truth Compliance	.165	-								
3. AC	-.056	-.029	-							
4. WMC	-.065	-.081	.203*	-						
5. Lie Early CEPR	-.065	-.148	-.065	-.041	-					
6. Truth Early CEPR	.102	-.103	-.141	.004	.303**	-				
7. Lie Late CEPR	.094	-.076	.050	.080	.056	.008	-			
8. Truth Late CEPR	-.122	-.064	-.027	.017	.097	-.177	.124	-		
9. Lie CEPR SD	-.048	-.005	-.036	.064	-.031	.048	-.077	.026	-	
10. Truth CEPR SD	-.012	.110	.011	-.034	-.057	-.025	-.001	-.061	.644**	-

Multiple Regression

Next, overall compliance rates and individual compliance rates for truth and lie trials were regressed on the predictor variables WMC, AC, early CEPRs, late CEPRs, and CEPR SD using several multiple regression analyses. For each analysis, the predictors matched the criterion measure, such that measures were calculated individually for lie trials, truth trials, and for the combined trial types to predict overall compliance, and compliance for the individual response types. In all analyses, none of the variables significantly predicted compliance as shown in Table 3.

Table 3: Results of the regression analyses that predict Compliance.

	Predictor	*β*	*SE*	*Beta*	*t*	*F*	*Adj.* R^2
Lie Compliance						.429	-.024
	AC	-.003	.006	-.042	-.445		
	WMC	-.004	.007	-.052	-.552		
	Early CEPR	.080	.079	.094	1.018		
	Late CEPR	.051	.166	.029	.307		
	CEPR SD	-.036	.082	-.041	.444		
Truth Compliance						.837	-.007
	AC	-.002	.006	-.035	-.367		
	WMC	-.005	.007	-.069	-.739		
	Early CEPR	-.092	.072	-.119	-1.265		
	Late CEPR	-.124	.146	-.079	-.847		
	CEPR SD	.080	.073	.100	1.094		
Overall Compliance						.665	-.014
	AC	-.002	.004	-.042	-.444		
	WMC	-.004	.005	-.074	-.784		
	Early CEPR	-.034	.072	-.043	-.467		
	Late CEPR	-.209	.155	-.125	-1.352		
	CEPR SD	.004	.065	.006	.061		

As a final exploratory analysis, CEPR SD (variability) was regressed on the cognitive variables WMC and AC, to determine if they predict variability in the changes in pupil diameter across the fixation interval for either response type. As in the regression analysis assessing the variable's ability to predict compliance, separate analyses between trial types were performed, as well as a final analysis with the trial types combined. None of the results for these analyses reached significance (all *p's* > .423).

CHAPTER FOUR

DISCUSSION

Discussion

The goal of this experiment was to determine any differences in the preparatory control of attention when individuals were anticipating telling a lie and when they were anticipating telling the truth. To do this, a paradigm was borrowed from a previous experiment (Hood et al., 2022) testing differences in the preparatory control of attention when anticipating trials of varying difficulty in the antisaccade task using CEPRs as the primary measure of changes in attention. Specifically, the changes in participant's pupils were measured during a fixation interval preceding the presentation of questions that they were instructed to answer truthfully or dishonestly according to a pre-fixation prompt. Participant's AC and WMC were also measured using a cognitive test battery composed of two complex span tasks used to assess WMC, and three novel Squared tasks used to assess AC, to determine if individual differences in either cognitive construct moderated CEPR patterns. Finally, equipment failure prevented the analysis of participant's verbal RTs when answering questions and their comparison to CEPR patterns.

Hood et al. (2022) found individual differences in WMC to moderate CEPR patterns between participants, such that those low in WMC exerted effort early in the fixation interval, continued exerting effort throughout the fixation interval, and committed more errors on antisaccade trials. Additionally, they found that those high in WMC exerted effort only in the final few seconds of the fixation interval and committed less errors on antisasccade trials. In measuring both WMC and AC, the goal of the current experiment was to replicate these results and to extend them using measures of AC as it is considered fundamental to the maintenance of goal-related information and suppression of goal-unrelated information that is characteristic of WMC (Engle, 2002, 2018), and because changes in pupil diameter are thought to represent variations in attentional mechanisms (Unsworth & Robison, 2017). It was hypothesized that CEPRs would be greatest in anticipation of trials in which participants were instructed to lie, and that WMC and AC would correlate negatively with overall compliance (proportion of errors committed) and positively with increased CEPRs in the few seconds preceding question onset. Finally, it was hypothesized that CEPR variability would correlate positively with overall compliance.

Results did not support the main hypotheses, which was largely driven by an opposing CEPR pattern of pupil constriction relative to the pattern of pupil dilation in the fixation interval found in Hood et al. (2022). Larger CEPRs were observed for lie trials than for truth trials; however, the differences were shown to be in pupil constriction across the fixation interval, which did not match one of the main hypotheses. This would suggest that participants were disengaging more from the task during the more complex trials relative to baseline pupil measurements. Additionally, as the current study's variables were being compared to Hood et al. (2022) in their differences in complexity, with antisaccade and prosaccade trials from the former study compared to lie trials and truth trials in the current study respectively, other findings from the current study did not conceptually replicate the former study's findings as well. For example, Hood et al. (2022) found larger baseline pupils preceding prosaccade (easier) trials, whereas the current study found larger baseline pupils preceding lie (harder) trials. However, findings in baseline pupil measurements consistent with the former study were shown as well, in that baseline pupils were larger preceding error trials than accurate trials, and that WMC was uncorrelated with baseline pupil measurements for either trial type. Regarding compliance, the finding that participants committed more errors on truth trials than on lie trials replicates Maldonado et al. (2018), and considering a similar questionnaire was used in both studies, it may suggest truthful responses were more difficult than lie responses for this paradigm. Perhaps most unfortunately, CEPR patterns were unrelated to both WMC and AC. These differences in findings raise questions about potential confounding variables, the paradigm and its demonstration of truthful responses as being more difficult than lie responses, and the general differences between the tasks used in Hood et al. (2022) and the current study. In the following, reasoning is given for what may have caused these differences in findings between these studies, as well as limitations and future directions for this research.

Differences in Luminance

One potential confounding variable that may have caused the opposing CEPR patterns between the current study and Hood et al. (2022) is the difference in the luminance levels between the calibration screen and the fixation screen presented throughout blocks of trials. The pupil light reflex is the term given to the observation of pupils constricting when introduced to light and dilating when introduced to darkness (Mathôt, 2018). According to Holmqvist et al. (2011), changes in pupil diameter are more sensitive to variations in luminance than they are to any sensory, cognitive, or emotional events, and the velocity of pupil constriction is three times greater than the velocity of pupil dilation. Although pupils are very responsive to auditory stimuli (Zekveld et al., 2018), with a latency in pupil dilation estimated to occur approximately 500-600 ms following the onset of an auditory stimulus (Beatty, 1982; McCloy et al., 2016), any internal processes driving changes in pupil diameter were possibly overwhelmed by the perceived and actual brightness of the light in the testing environment. It is likely that participant's pupils dilated upon hearing the prompt, but quickly constricted due to the brightness of the trial screen's background, a mishap attributable to a costly error on the part of the researcher. The larger observed baseline pupils following the lie prompt relative to the truth prompt are promising, because this means that this effect extended through the 1,000 ms period between the prompt presentation and the beginning of the 5,000 ms fixation interval when CEPRs were measured, when pupil constriction was observed.

Although there is no suggested standard luminance level for presentation screens, it is recommended that the luminance levels be approximately equivalent between the calibration screen where pupil sizes are initially measured and the subsequent screens where stimuli are presented (Holmqvist et al., 2011). The luminance level for the calibration screen was not mentioned in Hood et al. (2022), or the former study it replicated and extended (Hutchison et al., 2020), but both studies mentioned that the luminance levels for the background of their prompt screens and main trial screens were 29 cd/m^2 and 30 cd/m^2, respectively. Because the same equipment was used in the current study, it is assumed that the calibration screen luminance level remained the same as in the former studies at 14 cd/m^2. However, the luminance level for the background of the fixation screen used throughout blocks of trials in the current study was 90 cd/m^2, which is much brighter than the calibration screen used continuously in the three studies mentioned. None of these luminance measurements are considered in the context that the former two studies took place in a different room with windows allowing in sources of ambient light, and the current study was performed in a windowless room with ambient fluorescent light shining down on participants throughout the experimental procedures. This ambient light difference may have altered the luminance measurements for the calibration screen as well. The fixation cross in the middle of the fixation screen was closer in its luminance level to the calibration screen than it was to the background of the fixation screen. However, the bright background may have affected participant's pupils even if they were attempting to only attend to the fixation cross, and especially if they looked away from the fixation cross at any moment during the fixation interval, with covert attention paid to the background screen possibly affecting pupil size as well (Mathôt, 2018). A positive note is that this error is very easily reparable in future experimentation.

Task Differences

Task differences between the antisaccade task used in Hood et al. (2022) and the deception task used in the current study may also have contributed to the current findings. The antisaccade task has very clear goals of looking either away from or toward a flashing cue that appears briefly before a stimulus is rapidly presented. Additionally, feedback was given after each response showing the participant real-time evaluations of their performance. This feedback may have served as both a reminder to stay focused on the task, and a motivator to perform well. The differences in difficulty between prosaccade and antisaccade trials is apparent, given that antisaccade trials require AC for optimal performance and prosaccade trials simply require participants to naturally orient their attention toward a flashing stimulus. The antisaccade task is effective for assessing AC (Engle, 2018), but it does not require individuals to retrieve information from long-term memory apart from keeping the task's goals in mind while it is being performed. The antisaccade task also presented participants with three practice blocks, consisting of a total of 36 trials, and two test blocks, consisting of a total of 240 trials, which is far more trials than participants completed in the deception task. Finally, it should be mentioned that the antisaccade task presents participants with a visual task indicator, cue, and stimulus.

The deception task used in the current study also has clear goals of telling the truth or telling a lie to upcoming questions, but there are many differences between it and the antisaccade task. The lack of visual stimuli presented during trials, and the focus on answering questions based on participants' autobiographical information likely drew attention inward, so that information could be effectively retrieved from long-term memory. This retrieval process requires AC but is more dependent on accessibility of long-term memories making it more complex than simply having to look in the same or opposite direction of a stimulus. There was no feedback given after trials in this task, so participants may have been less aware of their performance, and may have been less motivated and focused on the task compared to participants in Hood et al. (2022). The questions in the deception task were presented much slower than the cue and stimulus were presented in the antisaccade task, which may have caused participants to relax their attentional state because they knew paying close attention to very rapidly presented stimuli is not as necessary for performance in the deception task. The number of trials completed in the deception task (44 total trials including practice) was much fewer the number of trials completed in the antisaccade task. The much larger number of trials completed in the antisaccade would suggest more potential for mental fatigue relative to the deception task, although the results suggest the opposite pattern regarding mental fatigue between these two studies, which is more suggestive of luminance affecting the findings in the current study. Finally, unlike the more easily discriminable differences in task difficulty in the antisaccade task, the differences in complexity between telling lies and telling the truth may not have been as obvious in the current study.

There are a few potential ways these task differences may have contributed to the current study's findings. The difference in stimulus modality between the two studies may have altered participants' attentional states, in that the visual task indicators in Hood et al. (2022) may have oriented participants' attention toward anticipating a very rapidly presented visual cue and stimulus requiring heightened AC during antisaccade trials. Conversely, the deception task in the current study presented participants with only auditory stimuli, and the question presentation occurred much slower than the cue and stimulus in the antisaccade task. These differences potentially suggest that the constriction pattern observed in the current study was caused by uncertainty that resulted from using only auditory stimuli with no visual anchors to orient participant's focus, and less of a need to pay attention to very rapidly presented stimuli. Additionally, feedback given to participants after each trial in the antisaccade task may have motivated their performance, and subsequently affected their attentional state. With no feedback given in the deception task, participants may not have experienced this same motivation and attentional boost, which would have contributed to their disengagement from the task and the constriction patterns observed.

The Complexity of Telling the Truth

Although the difference was marginal, participants committed more errors on truth trials than on lie trials in the current study. Maldonado et al. (2018) similarly found participants committed more errors on truth trials, and that most of the truth errors in their study were committed by participants low in WMC. These findings are interesting because they suggest that telling the truth may have been the more demanding trial type, a notion that directly opposes the premise underlying the ADCAT theory that lying is generally more cognitively demanding than telling the truth (Walczyk et al., 2014). Walcyzk et al. (2014) contends there are scenarios where lying is actually less demanding than telling the truth, due to inaccessibility of truthful information in long-term memory, or when telling lies that are generally prosocial that the liar knows will be received more favorably than the truth. However, in the current paradigm there are several ways in which participants may have produced an error when instructed to answer truthfully, and only one way to produce an error when instructed to answer dishonestly. Additionally, the lack of consequences for either the act of lying, or more specifically, the act of lying convincingly, made it possible for participants to answer with agreeably implausible responses. This means that ridiculous answers given when instructed to lie would be considered compliant. The absence of fear of accountability that usually accompanies the act of lying may have made telling the truth more difficult than lying under the constraints of the current paradigm.

The difficulty in answering truthfully could have also been a result of the type of question asked. The questionnaire used in the current study was very similar to the one used in Maldonado et al. (2018), asking participants questions about well-known and highly accessible autobiographical information (e.g., "What is your birth year?"), as well as questions about information that is likely much less rehearsed (e.g., "What is your dream yearly salary?”). One reason participants may have committed errors when instructed to tell the truth is that, due to the unrehearsed nature of the information solicited by the question, participants may have simply forgotten what answer they wrote on the questionnaire. Conversely, it may have been the case that because half of the questions were preference-based (e.g., "What is your favorite drink?"), participants could have honestly changed their answers from what they wrote on the questionnaire when answering questions during the deception task. Although the changed answers would be truthful, they would be considered non-compliant. It is possible the truth for preference-based questions is a bit more nuanced than the truth for factual questions. Finally, another explanation is that some of the questions were asking about factual autobiographical information, but the questions pertained to other people that are close to the participant (e.g., "What is your father's job?"). It is possible that answering questions about others, even if they are very close in relation to the participant, may have caused the higher rates of error commission because they did not know the correct answers to some of the questions asked about their family and friends. It would be good as a future research direction to investigate what types of questions may be causing the larger number of truth errors committed across these studies.

Although there are no doubt situations where it is less cognitively demanding to lie than to tell the truth, it is still contended that lying is generally the more cognitively demanding task. It is unfortunate that RT data was not available to verify this contention. Suchotzki et al.'s (2017) meta-analysis revealed that RTs were reliably longer for lie responses than for truth responses across multiple paradigms. Considering the higher rate of truth errors committed using the current paradigm across separate studies, it is worthwhile in future studies to analyze errors and RT data separately for factual and preference-based questions. It is possible that the higher proportion of errors on truthful responses relative to lie responses is primarily observed in truth response errors committed when answering preference-based questions. However, the opposite pattern could also be true for questions about close others that participants do not know the true answers to. Additionally, if the RT effect ($RT_{Lie} > RT_{Truth}$) is only significant for factual questions and not for preference-based questions, it may suggest that preference-based questions requiring a truthful response are more cognitively demanding than preference-based questions requiring a lie response. However, participants may also be answering truthful factual questions more quickly than dishonest factual questions, while also committing more errors, indicating a speed/accuracy trade-off for these questions. Having RT data and analyzing the errors by whether they are factual or preference-based will help in answering these questions.

Future Directions

It is still possible that there is a pattern of pupil dilation preceding truth and lie questions once participants are cued on how they will answer upcoming trials. Although exploratory, the finding that pupils significantly decreased in preparation of lie trials where participants committed an error provides some support for this contention. This finding is consistent with the notion of tonic disengagement as posited by the adaptive gain theory (Ashton-Jones & Cohen, 2005), in which lapses of attention contribute to errors. Former studies demonstrating a preparatory effect in pupil size change in anticipation of stimulus presentation as a function of task difficulty also provide support for this contention (Kahneman & Wright, 1971; McCloy et al., 2016). The tasks used in these studies differ greatly from each other and from the current study, however, the current study is designed similarly with respect to levels of task difficulty, and the effect is predicted as robust across a variety of tasks (Beatty, 1982). Finally, former studies demonstrating task-evoked changes in pupil diameter differing between individuals of varying cognitive ability (Ahern & Beatty, 1979; Van der Meer et al., 2010) suggest the possibility of cue-evoked changes in pupil diameter differing between individuals of varying cognitive ability as well.

If a discrepancy in luminance level between the calibration and fixation screens is to blame for the opposing CEPR patterns observed in the current experiment, changes to the methodology are suggested in a retesting of the hypotheses. First, luminance levels will be held constant between the calibration and fixation screens. Next, a wider recording window will be used in capturing pupil measurements. It is possible that effectively capturing the change in pupil diameter in this preparatory attentional period between when the decision to be truthful or dishonest is made and the question to be answered is presented will require inspection of the dynamic shifts in pupil diameter patterns beginning before the prompt is presented and continuing until the question presentation terminates. At the very least, this wider recording window will allow inspection of possible changes in pupil size during the fixation interval relative to events immediately preceding or following it. Secondary to the proposed changes in luminance levels, the instruction screens at the beginning of the experiment will be presented visually and auditorily with recorded messages to ensure that all participants are aware of task requirements, and are not simply clicking through the instruction screens without reading them. The recording equipment will be repaired so participant's RTs can be recorded and potentially predicted by CEPR patterns as well as other measured variables. Finally, the proposed analyses of RTs and errors as a function of whether the question asked is factual or preference-based will be conducted to determine whether telling the truth may be more cognitively demanding than telling a lie as a function of the type of question being asked.

Limitations

A couple of limitations are also acknowledged. First, the compliance analyses for accurate and erroneous trials comprised only a minority of the total sample of participants, and accurate trials greatly outnumbered erroneous trials for almost all participants involved. Because these analyses were exploratory and underpowered, they should be interpreted with caution. Second, it is possible that participants did not fully read and therefore understand the requirements that were presented at the beginning of the deception task. They may have simply clicked through the instruction screens, which possibly affected their accuracy during the task. Presenting the instruction screen visually and auditorily with help ensure that all participants are aware of the deception task's demands.

Conclusion

In recounting (his mentor) Daniel Kahneman's criteria for what constituted a physiological measure of mental effort, Jackson Beatty stated, "task-evoked pupillary responses associated with cognitive function might provide a common metric for the assessment and comparison of information-processing load in tasks that differ substantially in their functional characteristics" (1982, p. 284). Although he was referring to TEPRs and not CEPRs, the sentiment of this statement holds true in the face of the surprising and humbling findings in the current study. With key changes to the experiment itself, the expectation for the next testing of these hypotheses is that there will be a pattern of dilation in the fixation interval between the prompt presentation and question presentation, and that this pattern will differ between truth and lie responses, and between individuals of varying cognitive ability. The methods will be approximately the same in the retesting of the hypotheses, with attentional control and working memory capacity measured, and cue-evoked pupillary responses during the fixation interval serving as the primary measure of preparatory control of attention. If supported, this would provide evidence for the notion that individual differences in cognitive ability may moderate one's preparatory control of attention exerted prior to lying, but once the decision to lie has been made.

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APPENDIX

PARTICIPANT QUESTIONNAIRE

Questions:

Please answer each question on this page truthfully. Write your responses in the blanks following each question.

1. Where were you born? ____
2. Where are you from? ____
3. What is your birth year? ____
4. What is your birth month? ____
5. What was your first car? ____
6. Who is your current employer? ____
7. What is your college major? ____
8. What is your father's job? ____
9. What is your mother's job? ____
10. How old is your mom? ____
11. How old is your dad? ____
12. What did you last eat? ____
13. When did you last eat? ____
14. Where was your father born? ____
15. Where was your mother born? ____
16. What is your best friend's name? ____
17. What is your house's exterior color? ____
18. How many siblings do you have? ____
19. How many pets do you have? ____
20. When did your parents get married? ____

21. What was your favorite birthday? ____
22. What is your favorite band? ____
23. What is your favorite color? ____
24. What is your dream car? ____
25. Who is your favorite athlete? ____
26. Who is your favorite teacher? ____
27. What is your favorite movie? ____
28. What is your favorite song? ____
29. What is your favorite season? ____
30. What is your dream job? ____
31. What is your favorite drink? ____
32. Who is your current hero? ____
33. What is your favorite hobby? ____

34. What is your favorite game? ____
35. What is your dream vacation country? ______________________________________
36. Who's your favorite actor or actress? ____
37. What is your favorite sports team? ____
38. What is your favorite TV show? ____
39. What is your most prized possession? ____
40. What is your dream yearly salary? ____