THE EFFECTS OF CHRONIC CANNABIS USE ON EYEWITNESS MEMORY AND NEUROPSYCHOLOGICAL FUNCTIONING

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THE EFFECTS OF CHRONIC CANNABIS USE ON EYEWITNESS MEMORY AND NEUROPSYCHOLOGICAL FUNCTIONING

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Eyewitness testimony is one of the most persuasive forms of evidence brought forth in legal proceedings, despite a large body of research documenting the inaccuracies of memory. A variety of system and estimator variables influence the quality of eyewitness memory, such as lineup, event, and witness characteristics. Researchers are increasingly interested in witness intoxication given the effects of substances on memory accuracy. However, investigations into such concerns are primarily focused on alcohol, while cannabis is largely ignored. In fact, there are only two studies to date investigating the effects of cannabis on eyewitness memory. This is concerning given the growing prevalence of cannabis use in the United States and the increased likelihood that police may come into contact with cannabis-using eyewitnesses. To that end, this study aimed to evaluate the effects of chronic cannabis use on eyewitness accuracy. Chronic cannabis users (n = 21; M_{age} = 27.24, SD = 7.25) and non-users (n = 19; M_{age} = 31.47, SD = 7.14) viewed a simulated crime video and provided a statement regarding the details of the event. Subsequently, participants viewed either a target-present or target-absent lineup and provided a rating of confidence in their selection (or rejection) from the lineup. Participants also completed a brief neuropsychological battery evaluating their cognition, particularly their verbal and visual learning and memory. Results suggest that chronic cannabis users and non-users did not differ significantly with regard to neuropsychological performance (defined as verbal and visual recognition) or eyewitness performance (defined as the number and accuracy of details recalled). Moreover, user status and lineup condition did not predict lineup identification accuracy, and Rey-Osterrieth Complex Figure Test Recognition Trial (ROCFT RT) performance did not mediate the relationship between user status and lineup identification accuracy. Although greater power is needed to establish the reliability of findings from the present study, effect sizes were generally small, suggesting that significant differences in a larger sample are unlikely to be clinically important. Thus, results reported herein have the potential to inform

legal decision-making among judges and jurors as it pertains to the admissibility of eyewitness testimony or the rendering of a verdict.

The Effects of Chronic Cannabis Use on Eyewitness Memory and Neuropsychological Functioning

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INTRODUCTION

Prosecutors often utilize eyewitness testimony during trial, despite ample literature documenting a large degree of eyewitness error (Benton, Ross, Bradshaw, Thomas, & Bradshaw, 2006). Unfortunately, judges and jurors have difficulty distinguishing between accurate and inaccurate eyewitnesses, which may lead to damaging consequences, such as wrongful conviction (Wise, Dauphinais, & Safer, 2007). To reduce the court's reliance on potentially erroneous testimony, it is important to further clarify the factors that influence eyewitness accuracy. Variables such as stress, post-event information, and intoxication are just several factors of many that affect the accuracy of eyewitness memory (Benton, Ross, et al., 2006). Of those variables, researchers are increasingly interested in witness intoxication due to the direct effect of substances on memory and the high frequency of police contact with intoxicated witnesses (Evans, Schreiber Compo, & Russano, 2009; Lezak, Howieson, Bigler, & Tranel, 2012).

Research regarding intoxicated eyewitness memory primarily focuses on the effects of alcohol. For example, Hagsand, Hjelmsäter, Granhag, Fahlke, and Söderpalm-Gordh (2013a) found that mock witnesses with greater levels of alcohol intoxication provided fewer details of a crime compared to those with lower levels of intoxication; however, the accuracy of the details was unaffected. While alcohol receives considerable attention in relation to the effects of substances on eyewitness accuracy, cannabis is largely ignored.

Investigating the effects of cannabis on eyewitness memory is particularly important given that acute and chronic cannabis use may be associated with deficits in the domains of learning and memory (Broyd, van Hell, Beale, Yücel, & Solowij, 2016; Ganzer, Bröning, Kraft, Sack, & Thomasius, 2016; Grant, Gonzalez, Carey, Natarajan, & Wolfson, 2003). Despite these findings, there are only two studies to date addressing the effects of cannabis on eyewitness memory specifically (Vredeveldt, Charman, den Blanken, Hooydonk, 2018; Yuille, Tollestrup, Marxsen, Porter, & Herve, 1998). The former study found that witnesses under the acute intoxication of cannabis recalled significantly fewer correct details immediately following a witnessed video event relative to sober witnesses; however, the number of incorrect details did not differ between groups. Although the authors failed to find a significant association between cannabis use and lineup identification performance, accurate intoxicated witnesses were significantly more confident than their sober counterparts among the target-present condition. In the latter study, Yuille et al. (1998) found that cannabis-intoxicated witnesses recalled significantly fewer details immediately following a staged event compared to those who received a placebo. However, when questioned a week later, group differences in the number of details recalled were no longer significant. Further, groups were similar with regard to the accuracy of details recalled, lineup identification performance, and their degree of confidence.

Given the lack of studies investigating the effects of cannabis on eyewitness memory, the present study aims to expand the current state of literature. Notably, information on the accuracy of eyewitness memory among cannabis users is needed to inform real-world practices in law enforcement. Such concerns are more important now than ever due to recent changes in cannabis legislation. Remarkably, a total of ten states and the District of Columbia (D.C.) have approved adult recreational cannabis use, and a total of 34 states have enacted laws allowing cannabis for medicinal purposes (National Conference of State Legislature [NCSL], 2019a; 2019b). Thus, although archival data revealed only 5% of intoxicated witnesses to be under the influence of cannabis, the number of cannabis-user eyewitnesses is expected to rise (Center for Behavioral Health Statistics and Quality [CBHSQ], 2015; Palmer, Flowe, Takarangi, & Humphries, 2013). As a result, it is critical to further investigate the effects of cannabis on eyewitness memory. However, prior to exploring the role of cannabis in eyewitness memory, it is essential to review the basic components of memory processes and accuracy.

Memory

Memory Storage and Processing

Memory is arguably the most fundamental cognitive function for successfully navigating everyday life. Memory primarily involves the encoding of information, which is stored for retrieval at a later point in time (Gazzaniga, Ivry, & Mangun, 2002; Lezak et al., 2012). However, given that we perceive an immeasurable amount of information on a daily basis, information must be partitioned to store only the most relevant pieces. This is done through various stages of information processing and involves several storage systems (Atkinson & Shiffrin, 1968; Boradbent, 1958). The degree of memory processing will ultimately determine whether information is retained in sensory, short-term, or long-term memory stores (Gazzaniga et al., 2002; Lezak et al., 2012).

Sensory memory. The first stage of memory processing takes place at the sensory level, where a significant amount of perceptual information is stored for a matter of seconds (Atkinson & Shiffrin, 1968; Balota, Dolan, & Duchek, 2000; Phillips, 1974). This information takes the form of a fleeting auditory or visual trace, otherwise referred to as echoic and iconic memory (Darwin, Turvey, & Crowder, 1972; Massaro & Loftus, 1996; Sperling, 1960). For example, an echoic memory may allow you to recall someone calling out, even after the stimulus is removed. This type of memory quickly decays unless it is further registered. Advanced registration depends on several factors, including the affective and attentional salience of the information, as well as one's predisposition to perception and responding (Lezak et al., 2012). For example, perceptual information associated with a robbery would likely be further registered given its attentional salience, unless an eyewitness was not prone to responding (e.g., if they were visually impaired, intoxicated, or in a hurry to get to an appointment). Ultimately, attending to perceptual information may be an active, controlled process or an automatic reflex, depending on the significance or salience of the information (James, 1950; Jonides, 1981; Leclercq, 2002).

Short-term memory. Information that is retained during the registration process generally enters the first phase of short-term memory, otherwise known as immediate memory (Lezak et al., 2012). Immediate memory serves as both a temporary storage system until information is more thoroughly processed and as a retrieval system of limited capacity (Atkinson & Shiffrin, 1968; Squire, 1986a). In particular, immediate memory is thought to maintain approximately seven pieces of information, "plus or minus two," for up to several minutes (Miller, 1956, p. 343). More specifically, individuals store an average of seven pieces of information before performance declines, though memory can be maximized through chunking, or the combining of information into meaningful units (Gazzaniga et al., 2002).

Immediate memory may also operate in conjunction with an executive subsystem that allows for the manipulation of information, which is referred to as working memory (Baddeley, 2000; Baddeley & Hitch, 1974).

Working memory facilitates cognitive processing and problem solving over a short duration of time under the controls of the central executive mechanism, also known as the supervisory attentional system (Gazzaniga et al., 2002; Norman & Shallice, 1986). The central executive system manages two subdivisions known as the phonological loop and the visuospatial sketch pad, which process language and visuospatial information, respectively (Baddeley & Hitch, 1974; Baddeley, 1992). Ultimately, working memory allows this information to remain active in the mind for the purpose of guiding behavior, eliminating reliance on external cues (Lezak et al., 2012). For example, an eyewitness may rely on working memory if they are preserving details of an event in their mind while making a phone call to report what has happened. Although working memory often involves information from sensory inputs, it may also include information obtained from long-term storage systems (Gazzaniga et al., 2002).

Commonly, information stored in immediate and working memory is accessible for several minutes; however, the duration can be extended for several hours through rehearsal, or the active process of mental repetition (Lezak et al., 2012). Information may also be accessed after a day or two if encoded in a separate short-term memory store. This kind of short-term memory may represent an intermediate stage for information processing, preceding more permanent storage in long-term memory (Melcher, 2001; Tranel & Damasio, 2002).

Long-term memory. Storage in long-term memory ultimately becomes possible through the process of consolidation, otherwise known as learning (Gazzaniga et al., 2002; Lezak et al., 2012). However, the consolidation of information does not necessitate passage through short-term memory stores and may occur in the absence of deliberate or intentional efforts (Gazzaniga et al., 2002; Lezak et al., 2012; Squire, 1986b). Learning that takes place without conscious effort is referred to as incidental learning and is the result of automatic processes (Shiffrin & Schneider, 1977; McLaughlin, 1965). For instance, an eyewitness may incidentally learn and remember the details of a crime devoid of conscious efforts. Other types of learning require effortful processing, such as rehearsal (Balota et al., 2000; Hasher & Zacks, 1979; Johnson & Hirst, 1991).

At its broadest level, long-term memory is divided into two organizing systems according to the nature of the information to be stored (Gazzaniga et al., 2002). These storage and retrieval systems are referred to as declarative and nondeclarative memory (Cohen & Squire, 1980; Squire, Knowlton, & Musen, 1993). Declarative, or explicit, memory contains information pertaining to facts and life events, which are accessed through a conscious effort (Squire et al., 1993). Alternatively, nondeclarative memory is an implicit storage system that is accessed subconsciously. Although researchers have proposed alternative subdivisions of memory, the declarative and nondeclarative classification system offers an effective structure for investigating memory proficiencies and deficiencies (Lezak et al., 2012).

Declarative memory. To further distinguish different types of information, declarative and nondeclarative memory are also divided into subsystems. Declarative divisions include episodic and semantic memory (Tulving, 1972). Episodic memory is autobiographical in nature, comprising information about our personal lives and experiences (e.g., memory for a witnessed crime). Conversely, semantic memory reflects our knowledge for facts about objects, language, and the world (e.g., knowledge that dialing 911 will connect you with an emergency dispatcher; Tulving, 1972).

Nondeclarative memory. Nondeclarative memory is also divided into several subdivisions including procedural memory, the perceptual learning system, classical conditioning, and nonassociative learning (Gazzaniga et al., 2002; Lezak et al., 2012; Schacter, 1987). Procedural memory stores information involving cognitive and motor skills (e.g., how to dial a phone to reach 911), whereas the perceptual learning system facilitates recall through priming, or the subconscious recognition of stimuli as a result of prior experience (Schacter, 1987; Squire et al., 1993). Perceptual learning is often demonstrated through word-stem completion tests in which individuals are briefly exposed to a word list and asked to complete a series of word stems (e.g., cr___ for the word crime). The enhanced tendency to complete word stems with words from the preceding list reflects the concept of priming (Schacter, 1987). On the other hand, classical conditioning and nonassociative learning are forms of memory with behavioral implications. For example, classical conditioning involves the pairing of an unconditioned stimulus (naturally elicits a response) with a neutral stimulus (elicits no response) until the neutral stimulus becomes conditioned (elicits the unconditioned response in the absence of the unconditioned stimulus; Gazzaniga et al., 2002). Conversely, nonassociative learning occurs when a behavioral response decreases as a result of habituation or increases as a result of sensitization, both following repeated exposure to a stimulus (Gazzaniga et al., 2002).

Neurobiology of Memory

Although several physiological processes are responsible for learning and memory, this section will briefly describe the processes involved in the consolidation of declarative memories given the explicit nature of eyewitness testimony. The consolidation of declarative memories primarily occurs in the hippocampus, which is located in the temporal lobe along with other memory-related structures, such as the subiculum and entorhinal cortex (Lynch, 2004). The hippocampus plays a vital role in the formation of long-term memories through the strengthening of synaptic connections, or the point of communication between two nerve cells, a process known as long-term potentiation (LTP; Gazzaniga et al., 2002; Lynch, 2004). However, the process of LTP cannot occur without activation of *N*-methyl-d-aspartate (NMDA) receptors, which are transmitter and voltage dependent (Gazzaniga et al., 2002; Lynch, 2004). More specifically, the excitatory neurotransmitter, glutamate, must bind with NMDA receptors when there is adequate excitatory input, allowing for LTP to take place (Gazzaniga et al., 2002; Lynch, 2004). Once consolidation occurs, memories are stored in the neocortex and the hippocampus is no longer required for the storage or retrieval of memories (Gazzaniga et al., 2002). Rather, episodic retrieval is associated with activation in the right prefrontal cortex and semantic retrieval is associated with activation in the left prefrontal cortex (Nyberg, Cabeza, & Tulving, 1996)

Memory Retrieval

Similar to the nature of consolidation or learning, the retrieval of information from memory storage involves both active (conscious) and automatic (unconscious) processes. For example, as mentioned earlier, the retrieval of declarative memories necessitates conscious efforts, whereas the retrieval of nondeclarative memories is outside of our subjective awareness (Lezak et al., 2012).

Declarative memories are retrieved, or remembered, through recall or recognition (Lezak et al., 2012; Squire, 1992). Recall involves a complicated searching process in which memories are independently retrieved from storage. Recall is further differentiated by free versus cued recall (Lezak et al., 2012). For example, the prompt, "Tell me everything you can remember about the crime you witnessed yesterday," would elicit free recall because there are no clues as to what the crime entailed. However, the prompt, "Tell me everything that happened after the thief stole the money," would elicit cued recall because it includes a cue regarding the nature of the crime. In contrast, recognition occurs when an individual accurately distinguishes previously encountered material from new material (Norman & O'Reilly, 2003). For example, when answering the question, "Who was the culprit of the crime: person A, B, or C?", one is tasked with recognizing which person was encountered previously.

Memory Accuracy

Given the remarkable amount of information that we process daily, it is unsurprising that our memories become less accurate and more difficult to access with the passage of time (Altmann & Gray, 2002). The occurrence of normal forgetting, the rate of which varies from person to person, may eventually result in the complete loss of information (Lezak et al., 2012). Several factors that influence rates of forgetting include age, development, and the subjective significance of remembered material (Lezak et al., 2012). However, new learning, along with disuse of old information, may also result in forgetting (Altmann & Gray, 2002; Squire, 1986a). The process in which new learning diminishes previously learned material is known as retroactive interference (Underwood, 1948). However, previously learned material may also diminish new learning, a process known as proactive interference (Still, 1969; Underwood, 1948).

Provided that forgetting inevitably occurs, the accuracy of our memories is sometimes called into question. However, the determination of accuracy may be difficult and partially depends on the nature of information being recalled. When retrieval involves information that is semantic in nature, evaluation of accuracy is often straightforward. For example, there is only one correct response to the question, "Who is the current president of the United States?" However, the accuracy of episodic information is generally difficult to determine. For example, a group of people may recall a single event differently due to their own subjective filtering and previous life experience. In such cases, distinguishing accurate and inaccurate recollections can be a challenging process.

Gist versus detail memory. Researchers have proposed several theories to better understand the accuracy of memory (Koriat, Goldsmith, & Pansky, 2000). One approach concerns memory for gist versus detail, which involves the appraisal of accuracy at various levels of generality (Koriat et al., 2000; Odegard & Lampinen, 2005). This theory holds that accuracy is much more likely when recalling the overall gist of information. For example, if a witness were asked to estimate the age of a perpetrator they may choose to state, "the individual was in their 30's," rather than, "the individual was 32 years old," to deliberately increase their chance of accuracy (Goldsmith & Koriat, 1999). Although research supports increased accuracy and retention for gist memory, memory for gist may still result in recall or recognition errors. For instance, a witness might erroneously recall that the perpetrator escaped in a "Toyota Tacoma" rather than the accurate model "Toyota Tundra" given that categorical information maintains a stronger representation in memory when compared to the specific target trace (Koutstaal & Schacter, 1997; Tun, Wingfield, Rosen, & Blanchard, 1998). In other words, the semantic category "Toyota truck" was remembered, though the specific model was not.

Schema-based memory distortions. Another framework for understanding memory accuracy and distortion is schema theory (Koriat et al., 2000). Schema theory maintains that recalled information is the result of integration of input with pre-existing schemas, which are organizing systems for general knowledge that are shaped by experience (Bartlett, 1932). There are five different schema processes that may influence information encoding or retrieval (Alba & Hasher, 1983). The first process involves selection, which concerns the quantity (rather than quality or accuracy) of remembered material. Specifically, selection suggests that information is more likely to be remembered if it can be integrated into pre-existing schemas, especially if it is central to the schema (Bransford & Johnson, 1972; Sentis &

Burnstein, 1979). For example, if a police officer were reading a manual outlining recommended eyewitness interviewing and identification procedures, they may be more likely to remember essential information if they have previously delt with an eyewitness.

The second process is abstraction, which occurs when incoming material is integrated with schematic representations, resulting in the loss of specific details (Alba & Hasher, 1983). If the subsequent remembrance of information requires details that are lost during abstraction, they are reconstructed according to the schema-based inferences, resulting in memory distortions (Bartlett, 1932). For instance, if a police officer were familiar with their department's eyewitness interviewing procedures, but were recalling recommendations from their manual, they may reconstruct the information according to what they learned in their department, which may lead to an erroneous recollection of the manualized procedures. The third process is interpretation, which involves direct manipulation of incoming information (Alba & Hasher, 1983). More specifically, schema-based inferences augment incoming material beyond its pure representation and are incorporated as part of the encoded memory (Koriat et al., 2000). Continuing with the previous example, a police officer's preexisting knowledge of eyewitness procedures will naturally influence their interpretation of recommended eyewitness procedures, which will modify the way in which the recommended eyewitness procedures are encoded to begin with.

The fourth process, integration, occurs when assorted pieces of information are blended into a cohesive schematic whole, which may occur during or following the process of encoding (Alba & Hasher, 1983; Loftus, Miller, & Burns, 1978). An integrated memory based off the narrative referenced above may consist of incoming information (recommended eyewitness procedures), interpretations drawn from the information (based off an officer's experience conducting eyewitness interviews), and relevant preexisting knowledge (related to an officer's previous training). Ultimately, integration may result in distorted recollections such as hindsight bias, which is overestimating the degree to which you believed something might happen subsequent to the actual outcome (Fischhoff, 1977; Hawkins & Hastie, 1990). Integration may also lead to the misinformation effect, which will be discussed in greater detail later.

The last process is reconstruction, which takes place during the retrieval of information (Alba &

Hasher, 1983). Essentially, reconstruction involves accessing the input material, which is now integrated with other schematic representations, to reproduce what was learned (Alba & Hasher, 1983). Ultimately, the recalled information often contains distortions due to schematic influence on encoding processes.

Source monitoring errors. Memory distortions may also occur when remembering the source of learned information (Koriat et al., 2000). These distortions are known as source monitoring failures, or inaccurate recollections of when, where, and how memories were constructed (Johnson, Hashtroudi, & Lindsay, 1993). For example, integrating post-event details into one's original memory for an event may be considered a source monitoring error. Often, these errors occur when the binding of different event elements is disrupted, interfering with the appropriate storage of information (Schacter, Norman & Koutstaal, 1998). Factors such as self-focus and divided attention at the time of encoding may interfere with adequate binding and storage, resulting in inaccurate source recollections (Craik & Byrd, 1982; Johnson, Nolde, & De Leonardis, 1996). However, others hypothesize that source confusion occurs with deficient source identification processes (Johnson, 1992).

Source monitoring is particularly important when evaluating the veridicality, or reality, of information, which is sometimes difficult to distinguish from imagined or fictional information (Finke, Johnson, & Shyi, 1988; Johnson, Kahan, & Raye, 1984). For example, researchers have found that imagined events become more vivid when individuals are instructed to think about them, resulting in source confusion and the conclusion that the events actually happened (Suengas & Johnson, 1988). Source monitoring is also necessary when deconstructing a memory to separate schematic and/or post-event information to solely recall the objective details (Koriat et al., 2000). For example, when an eyewitness is asked to provide a statement regarding a criminal event, the individual must use source monitoring to distinguish between objective details and intrusions, which may otherwise skew the accuracy of their statement.

Post-event misinformation. The post-event misinformation effect further illustrates the fallibility of memory (Koriat et al., 2000; Loftus & Hoffman, 1989). In particular, researchers have found that information introduced after an event may contaminate the original memory for that event, leading to false recollections (Loftus & Hoffman, 1989). This phenomenon was extensively tested using the misleading post-event information paradigm in which participants are purposely supplied misinformation about a witnessed event. One of the most cited of these paradigms is that of Loftus and colleagues (1978), who found that mock witnesses were more likely to remember stop signs as yield signs when exposed to misinformation in the form of a question (e.g., "Did another car pass the red Datsun while it was stopped at the yield sign?"; p. 22). This form of misleading information often results in false recognition errors, which are held in high confidence as true (Loftus, Donders, Hoffman, & Schooler, 1989).

The misinformation effect is more likely to occur with certain types of remembered details and under several conditions. For example, memory for peripheral detail is more susceptible to the misinformation effect compared to central detail (Cassel & Bjorklund, 1995; Heath & Erikson, 1998). In addition, longer retention intervals are more likely to produce recollections of misinformation (Belli, Lindsay, Gales, & McCarthy, 1994; Higham, 1998). Further, memories are more prone to contamination when misinformation is presented as part of a question, rather than a statement (Zaragoza & Lane, 1994). Presumptuous questions (i.e., "what color was the hat?") are also more likely to result in misinformation errors compared to open format questions (i.e., "what was the suspect wearing?"; Fiedler, Walther, Armbruster, Fay, & Naumann, 1996). Finally, repeated exposure to misleading details increases the likelihood of the misinformation effect, especially when repeated suggestions are encountered in different contexts (e.g., print, audiotape, and videotape) relative to a single context (Mitchell & Zaragoza, 1996).

Ultimately, the process of memory encoding, storage, and retrieval relies on a multifaceted system of cognitive functions, which together influence the quality and accuracy of memories (Lezak et al., 2012). However, there are a variety of additional factors that may moderate memory accuracy. For example, the simple passage of time results in the natural decay of memories, thus reducing accuracy. The degree of detail being recalled also determines the quality of memories, such that recollections of gist are often more accurate and have greater retention rates compared to recollections of specific details. In addition, schematic influences during encoding and retrieval processes, faulty source-monitoring, and misleading post-event information may distort the accuracy of memories. Given the large body of evidence supporting the fallibility of memory, it is essential to examine memory accuracy in the context of eyewitness testimony.

Eyewitness Testimony

A Brief History on Eyewitness Testimony

Although Hugo Münsterberg (1908) introduced the psychology of memory accuracy to the courtroom over a century ago, legal proceedings continue to rely on eyewitness testimony and identification (Howe & Knott, 2015; Wise & Safer, 2012). Eyewitness testimony generally refers to statements provided under oath regarding criminal or civil conduct and may include details regarding a witnessed event, culprit characteristics, or a lineup identification (a positive identification of a suspect from a lineup; Cutler & Kovera, 2010; Wells & Olson, 2003). Ultimately, eyewitness accounts, along with other forms of evidence, are considered when rendering a verdict.

Presently, despite the literature documenting the inaccuracies of memory, eyewitness testimony remains one of the most persuasive forms of evidence brought forth in legal proceedings (Howe & Knott, 2015; Smalarz & Wells, 2012). This is alarming given that nearly three decades of forensic DNA analysis suggest that inaccurate eyewitness identifications are the primary cause of wrongful conviction in DNA-exonerated cases (Wells et al., 1998). Introduced in the 1990's, DNA analysis allows investigators to cross-reference unknown DNA collected from the crime scene with that of a known suspect to determine whether they match (National Institute of Justice [NIJ], 2012; Wells et al., 1998). The discovery of DNA analysis has ultimately helped exonerate 442 innocents convicted between the years 1989 and 2017 (The National Registry of Exonerations [NRE], 2017). Remarkably, of the 442 DNA-exonerated convictions, 59% (261/442) were the product of mistaken eyewitness identification (NRE, 2017).

Although DNA analysis has helped exonerate a significant number of individuals, not all cases have DNA evidence to aid in proving one's innocence (Smalarz & Wells, 2012). Unfortunately, a lack of DNA evidence paradoxically leads to increased reliance on eyewitness testimony during trial (Smalarz &

Wells, 2012). This is particularly concerning given that the testimony of just one eyewitness is sufficient for criminal conviction in the United States, even in the absence of all other forms of evidence (Davis & Loftus, 2012). Ultimately, if legal proceedings are to continue relying on eyewitness evidence, safeguards are needed to protect against wrongful convictions. This is especially important in cases that may result in high-stake sentences such as life in prison or the death penalty.

Legal Safeguards Against Unreliable Eyewitness Testimony

Despite the fallibility of eyewitness testimony, courtrooms routinely welcome witnesses to the stand. This necessitates legal safeguards to reduce the likelihood that unreliable evidence results in wrongful conviction (Wise, Sartori, Magnussen, & Safer, 2014). Presently, these safeguards include presence-of-counsel, motion-to-suppress an identification, voir dire, provision of jury instructions, cross-examination, and expert testimony (Devenport, Kimbrough, & Cutler, 2009; Van Wallendael, Cutler, Devenport, & Penrod, 2007; Wise et al., 2014).

Presence-of-counsel. The Sixth Amendment affords accused individuals the constitutional right to counsel, a critical component of any legal proceeding (Supreme Court Review, 1978). However, the right to counsel extends beyond the trial itself and applies to various stages of pretrial confrontation (Supreme Court Review, 1978). For example, *United States v. Wade* (1967) established the right to have an attorney present at live post-indictment lineups, or lineups that occur after the grand jury has issued an official charge against the accused (American Bar Association [ABA], 2016; Wise et al., 2007). This allows the defense attorney to evaluate and oppose potentially suggestive lineup procedures, or procedures that may unfairly result in identification of the accused (Devenport et al., 2009; Wells & Quinlivan, 2009).

The success of the presence-of-counsel safeguard relies on attorneys' ability or willingness to attend their defendant's post-indictment lineups (Devenport et al., 2009). Yet, one sample of attorneys attended only 5% of their client's post-indictment lineups, suggesting the ineffectiveness of such a safeguard (Stinson, Devenport, Cutler, & Kravitz, 1996). However, beyond simply attending the lineup, attorneys must adequately understand suggestive lineup procedures (Devenport et al., 2009). One study assessing defense attorneys' sensitivity to lineup procedures revealed that, in general, they possessed adequate knowledge of factors influencing lineups (i.e., foil and instruction bias; Stinson et al., 1996). However, they were less familiar with the effect of lineup presentation (sequential vs. simultaneous) on misidentification rates, a finding consistent with current research (Stinson et al., 1996; Wise, Pawlenko, Safer, & Meyer, 2009). Overall, presence-of-counsel is a limited safeguard and will likely remain as such given that little is done to encourage representation during lineup procedures (Van Wallendael et al., 2007).

Motion-to-suppress. In the case that a positive identification is obtained using unduly suggestive lineup procedures, attorneys may issue a motion-to-suppress to prevent the identification from being entered into evidence at trial (Wise et al., 2014). However, if the judge determines the identification was reliable despite suggestive procedures, the identification is admissible in court (Epstein, 2013; Wise et al., 2007). Reliability of the identification is evaluated using several criteria, which were first articulated in *Neil v. Biggers* (1972) and again in *Manson v. Brathwaite* (1977; Devenport et al., 2009; Wise et al., 2007).

The reliability evaluation involves a test of two prongs: the trier of fact first determines whether the identification was obtained using unnecessarily suggestive procedures (Wells & Quinlivan, 2009). If suggestive procedures are evident, the identification is evaluated against five additional factors (Wells & Quinlivan, 2009). These factors include: (1) the witness's opportunity to view the perpetrator at the time of the offense, (2) the witness's level of attention, (3) the length of time between the offense and the witness's identification, (4) the degree of witness certainty following the identification, and (5) whether the witness's initial description of the criminal was accurate (Epstein, 2013; Wise et al., 2007). After evaluating the "totality of the circumstances," judges decide whether the identification is admissible (*Stovall v. Denno,* 1967, p. 388 U.S. 305; Wells & Quinlivan, 2009).

Although the reliability criteria are used to evaluate the credibility of an eyewitness identification, research does not suggest that the criteria are reflective of eyewitness accuracy. The criteria were developed prior to advancements in the eyewitness literature and therefore do not account for important factors that minimize the function of each criterion (Wise et al., 2007). For example, the first of the five factors assumes that witnesses with ideal viewing conditions will be more accurate compared to those with poor viewing conditions (Wise et al., 2007). However, this relies on the assumption that eyewitnesses are accurate in their appraisals of their viewing conditions (Bradfield, Wells, & Olson, 2002; Wise et al., 2007). Similarly, the relationship between witness level of certainty and identification accuracy is weak at best, particularly if one's degree of certainty is expressed at the time of the trial rather than at the time the identification is obtained (Sporer, Penrod, Read, & Cutler, 1995; Wise et al., 2007). Moreover, the criteria are simply incomplete without consideration of relatively recently identified influences on accuracy such as lineup instructions, lineup format, witness age, and witness intoxication (Wise et al., 2007).

Additionally, due to the first prong of a reliability evaluation, the utility of the reliability guidelines depends on judges' understanding of factors relevant to lineup identification procedures (Benton, Ross, et al., 2006; Van Wallendael et al., 2007). One early study of applied knowledge indicates that judges, like defense attorneys, have some knowledge of suggestive identification procedures (e.g., foil and instruction bias; Stinson, Devenport, Cutler, & Kravitz, 1997). However, they are less familiar with the effects of lineup presentation on rates of misidentification (Stinson et al., 1997). Similarly, a survey assessing judges' knowledge of eyewitness factors found that judges were less likely to agree with eyewitness experts on the impact of several lineup variables, including lineup instructions, presentation format, and description matching (Benton, Ross, et al., 2006). Although a more recent survey found agreement rates of 67% between judges and experts, judges still lacked knowledge of important factors (e.g., exposure duration, cross-race effect, weapon focus, and the confidence-accuracy relationship; Houston, Hope, Memon, & Read, 2013).

Voir dire. Given that judges may admit identifications obtained under unnecessarily suggestive procedures, a defense attorney may take additional steps to protect their client from such evidence (Wise et al., 2014). One of these steps involves jury selection, otherwise known as voir dire, a phrase that translates as "to see them talk" (Suggs & Sales, 1980, p. 245; Wise et al. 2014). During voir dire, attorneys are permitted to excuse jurors who are reluctant or unable to critically evaluate eyewitness reliability (Wise et al., 2007). However, this safeguard necessitates an effective strategy for identifying such jurors (Wise et al., 2007) and there are no valid means to assess jurors' attitudes or beliefs with regard to eyewitness testimony (Wise et al., 2014). Currently, there is only one scale that exists for this purpose, the Attitudes Toward Eyewitnesses Scale, which contains nine Likert-type statements pertaining to eyewitness factors (Narby & Cutler, 1994; Wise et al., 2014). Unfortunately, the scale has demonstrated only minor success as a tool for predicting how mock jurors evaluate the reliability of eyewitness testimony (Devenport & Cutler, 2004; Devenport, Stinson, Cutler, & Kravitz, 2002; Narby & Cutler, 1994). Furthermore, some courts greatly restrict the opportunity for attorneys to question jurors or eliminate this process altogether (Crocker & Kovera, 2011; Devenport et al., 2009; Wise et al., 2014). As a result, the use of voir dire to protect defendants from over-reliance on eyewitness identifications obtained under suggestive procedures is insufficient.

Jury instructions. Jury instructions serve to guide jurors in the decision-making process (Devenport et al., 2009). They may be used as a safeguard against unreliable eyewitness testimony if they include special warnings to jurors regarding eyewitness variables (Devenport et al., 2009; Wise et al., 2014). Unfortunately, not all courts require that jurors receive cautionary eyewitness instructions and there is no consistent method for their delivery (Sheehan, 2011). Remarkably, there is only one instance in which warnings of eyewitness reliability are required: when the sole evidence against the accused is that of a single eyewitness (*United States v. Telfaire*, 1972; Wise et al., 2007). In the event that cautionary instructions are provided to jurors, most are modeled after the *Telfaire* instructions (Devenport et al., 2009; *United States v. Telfaire*, 1972). These instructions specifically encourage jurors to consider the same eyewitness criteria set forth in *Biggers* (1972) and *Brathwaite* (1977; Sheehan, 2011; Wise et al., 2014).

In order for cautionary eyewitness instructions to be effective, they should increase jurors' sensitivity to empirically supported factors that impact eyewitness accuracy (Bornstein & Hamm, 2012). In theory, jurors with adequate sensitivity can adjust their reliance on eyewitness evidence after careful consideration of evidence quality (Bornstein & Hamm, 2012). So, when afforded, how helpful are the *Telfaire* instructions in sensitizing jurors to eyewitness testimony? Currently, the literature suggests that special instructions are minimally useful for this purpose (Bornstein & Hamm, 2012; Sheehan, 2011). In general, jurors have difficulty understanding how eyewitness factors (i.e., viewing conditions, attention) affect the reliability of memory, specifically for the case at hand (Devenport et al., 2009).

In hopes of increasing jurors' understanding and sensitivity to the *Telfaire* instructions, several researchers have sought to simplify them through a series of mock-juror studies (Bornstein & Hamm, 2012; Greene, 1988; Ramirez, Zemba, & Geiselman, 1996). Though jurors better understood simplified instructions, their sensitivity to eyewitness factors did not meaningfully improve, even when researchers modified the instructions beyond simplification (e.g., providing written and verbal instructions, interactive instructions, etc.; Bornstein & Hamm, 2012). At best, the modified instructions increased juror skepticism (Greene, 1988; Ramirez et al., 1996), which reduces jurors' tendency to convict, regardless of evidence quality (Cutler, Dexter, & Penrod, 1989; Jones, 2015). New Jersey utilizes instructions more consistent with the scientific literature; the *Henderson* instructions provide a comprehensive review of the mechanisms of memory, how such mechanisms apply to the case at hand (e.g., how stress, presence of a weapon, intoxication, etc., may alter witnesses' opportunity to view), and the misleading nature of eyewitness identification evidence, particularly in the context of suggestive identification procedures (New Jersey Supreme Court, 2012; Papailiou, Yokum, & Robertson, 2015). However, similar to the effect of the *Telfaire* instructions, exposure to the *Henderson* instructions did not enhance juror sensitivity (Jones, 2015; Papailiou et al., 2015), and instead induced skepticism (Papailiou et al., 2015).

Despite the minimal research demonstrating an effect on juror sensitivity, specialized instructions have the potential to act as a safeguard, provided that they are delivered with an appropriate explanation (Wise et al. 2007). For example, a number of researchers propose a "point-by-point" approach to addressing each eyewitness criterion while challenging jurors' erroneous assumptions along the way (Ramirez et al., 1996; Wise et al., 2007, p. 27). The recommended approach simulates a set of cautionary instructions set forth in *People v. Wright* (1988) and *State v. Larry R. Henderson* (2011), which are tailored to help jurors identify pertinent eyewitness factors in a case (Devenport et al., 2009). Unfortunately, the widespread provision of such flexible instructions is unlikely considering they must be carefully adapted for each case (Wise et al., 2007). This flexibility creates room for error, which may result in verdict appeals. Thus, judges are generally hesitant to adopt such a flexible practice (Wise et al., 2007).

Ultimately, although courts may adopt specialized jury instructions to fit the case at hand, most instructions are comparable to those articulated in *United States v. Telfaire* (1972), which fail to consider important factors impacting eyewitness accuracy (Wise et al., 2007). However, it does not appear that inclusion of scientifically-based factors (e.g., New Jersey *Henderson* instructions) produces significant gains (Jones, 2015; Papailiou et al., 2015). Researchers have developed an alternative method for increasing juror sensitivity to eyewitness factors, the interview-identification-eyewitness factor (I-I-Eye) method, in an attempt to overcome the limitations of other approaches (Pawlenko, Wise, Shafer, Holfeld, 2013). This method helps jurors evaluate eyewitness reliability through the appraisal of police interviewing procedures, police identification procedures, and witnessing conditions. To finish, jurors are questioned about the testimony, which aids them in their evaluation (Pawlenko et al., 2013; Wise, Fishman, & Safer 2009). Preliminary research assessing this method has found increased mock-juror sensitivity to eyewitness factors (Pawlenko et al., 2013).

Cross-examination. Cross-examination is the most commonly employed method to safeguard against unreliable eyewitness testimony, in part because it is believed to be effective (Wise et al., 2007). Cross-examination refers to the process in which an attorney questions the opposing counsel's witness to gauge their credibility (Devenport et al., 2009; Epstein, 2007). However, the effectiveness of this tactic is limited, as several conditions must be met to garner any benefit (Wise et al., 2014). To begin, attorneys must understand the factors influencing eyewitness reliability to expose such information to the jurors through cross-examination (Wise et al., 2014). Jurors must also have sufficient knowledge of eyewitness factors to appreciate the implications of cross-examination. Moreover, jurors must utilize those factors to inform decision-making about the case (Wise et al., 2014). Thus, for cross-examination to be successful, it is imperative that jurors understand the implications of the information it elicits (Wise et al., 2007; Wise et al., 2014).

As mentioned previously, defense attorneys' knowledge of suggestive lineup procedures is limited, which may restrict their ability to expose unreliable eyewitness identifications (Stinson et al., 1996; Wise, Pawlenko, et al., 2009). However, they do understand some important factors (e.g., lineup administration bias, foil bias, eyewitness confidence, post-event information, etc.), facilitating their cross-examination efforts (Wise, Pawlenko, et al., 2009). Surveys assessing jurors' knowledge of eyewitness factors are mixed, raising concern regarding jurors' ability to appreciate the information gleaned during cross-examination. For example, one survey found that a sample of actual jurors' responses ("generally true," "generally false," or "I don't know") to statements pertaining to eyewitness factors were generally inconsistent with empirical research (e.g., lineup instructions, presentation format, lineup fairness, post-event information, exposure time, etc.; Benton, Ross, et al., 2006). However, several other surveys found that jurors were knowledgeable with regard to factors impacting eyewitness accuracy (e.g., lineup instructions, exposure time, cross-race bias, post-event information, etc.), especially when surveys were presented in multiple choice format rather than open format (Houston et al., 2013) and when contextual information was provided (e.g., descriptions of eyewitnesses' roles; Read & Desmarais, 2009). Unfortunately, jurors' inconsistently apply their knowledge when rendering a verdict. For example, one study in which mock jurors viewed a videotaped trial found that mock jurors were adequately sensitive to cross-examination efforts eliciting concern regarding foil bias, which carried over into subsequent decision-making, but not to lineup instruction or presentation bias (Devenport et al., 2002).

Further complicating jurors' appraisal of eyewitness accuracy is the inherently flawed nature of conventional cross-examination, including flawed assumptions about the ways in which an accurate and truthful eyewitness should react relative to one who is inaccurate or deceitful (Henderson, 2015). The former is expected to display resistance to suggestion, consistent testimony, and a composed, confident demeanor. Given that such characteristics are thought to distinguish accurate from inaccurate witnesses, cross-examination often utilizes intense interrogation and probing in an effort to elicit suggestibility, inconsistency, and wavering confidence (Henderson, 2015). In doing so, defense attorneys may have difficulty discrediting an honest but mistaken eyewitness who appears confident and credible (Epstein, 2007; Sheehan, 2011). As a result, cross-examination that intends to diminish an eyewitness's credibility may actually do the opposite (Epstein, 2007; Wise et al., 2007). For instance, cross-examination may elicit information that jurors consider to be memory-enhancing factors, despite conflicting scientific evidence (e.g., presence of a weapon or subjective stress; Epstein, 2007). However, even more powerful is the tendency for jurors to sympathize with witnesses (Wise et al., 2007). This may make it difficult for jurors to disregard eyewitness evidence, even when explicitly asked to do so (Steblay, Hosch, Culhane, & McWethy, 2006).

Expert testimony. Given that cross-examination may be insufficient for sensitizing jurors to unreliable eyewitness testimony, expert witnesses may be called to testify on the reliability of eyewitness evidence (Wise et al., 2014). Eyewitness experts use their knowledge and expertise in the field to identify for jurors the factors that may have influenced eyewitness accuracy (Golan, 2008; Wise et al., 2007). However, like alternative safeguards, the use of eyewitness experts is not universally permitted (Davis & Loftus, 2012). To illustrate this issue, Benton, McDonnel, Thomas, Ross, and Honerkamp (2006) reviewed 51 of the recent court cases across the U.S. that sought to introduce an expert on eyewitness accuracy and found that judges permitted the expert to testify only 9% of the time. This reflects the discretionary nature of expert witness admissibility, despite a set of parameters intended to guide judges in their decision-making (Sheehan, 2011).

The first standard for expert admissibility was derived from *Frye v. United States* (1923), which held that expert testimony based upon a scientific technique must demonstrate general acceptance of that technique in the field to which it belongs. However, the Supreme Court later determined in *Daubert v. Merrell Dow Pharmaceuticals, Inc.* (1993) that Rule 702 of the Federal Rules of Evidence (FRE) superseded the *Frye* standard. FRE 702 requires that experts' testimony help the trier of fact evaluate the evidence or determine a fact, be based on sufficient data, be derived from reliable principles and methods, and be appropriately applied to the facts of the case (Testimony by Expert Witnesses, 2018). *Daubert* also detailed four criteria to aid judges in determining the reliability of expert testimony, including whether the theory or technique has been (or can be) tested, whether it has undergone peer review and publication, rates of identified or potential error, and whether it has drawn general acceptance in the scientific community; however, these criteria are neither necessary nor sufficient for the admission of expert testimony under the *Daubert* decision (Morey, Warner, & Hopwood, 2007). Although FRE 702 and *Daubert* supersede the *Frye* standard under federal law, several jurisdictions continue to rely on *Frye* as a basis for expert admissibility (Morgenstern, 2016). Prosecutors may also put forth arguments against the admission of expert witnesses, which judges consider in their discretion (Wells, Memon, & Penrod, 2006). The three most compelling arguments against admitting expert testimony on eyewitness accuracy are that 1) expert testimony invades jurors' province, as they are the ones who must determine witness credibility, 2) the effects of eyewitness factors are common sense for jurors (despite evidence suggesting the opposite), and 3) the consequences of expert testimony (i.e., juror skepticism) outweigh the potential benefits (Wells et al., 2006). Regrettably, these arguments often preclude the use of expert witnesses (Wells et al., 2006).

When an expert witness is admitted to testify, there are three possible outcomes (Cutler, Penrod, & Dexter, 1989). One possibility is that expert testimony has no effect on juror decision-making, particularly if it confuses or fails to persuade them (Cutler, Penrod, & Dexter, 1989; Wise et al., 2014). Second, testimony may induce juror skepticism, which may lead them to discredit all eyewitnesses regardless of reliability. Third, testimony may enhance juror sensitivity, thereby improving the application of eyewitness factors to the case at hand (Cutler, Penrod, & Dexter, 1989; Wise et al., 2014). Although expert testimony most often results in juror skepticism (Leippe & Eisenstadt, 2009; Levett & Kovera, 2008; Wise et al., 2014), sensitivity is sometimes attained (Devenport et al., 2002; Martire & Kemp, 2011).

Despite the potential for expert testimony to safeguard against unreliable eyewitnesses, there are several additional issues inherent in this method (Sheehan, 2011; Wise et al., 2007). Most concerning is the steep cost of expert testimony in terms of both time and money (Sheehan, 2011; Wise et al., 2007). For example, data compiled from over 20,000 expert witnesses suggests that psychology experts charge an average of $427 per hour for in-court testimony (The Expert Institute, n.d.). This cost multiplies quickly due to the substantial amount of time devoted to expert testimony and related activities (e.g., record review, preparation, trial testimony; SEAK, 2016; Sheehan, 2011). Although some defendants can afford experts, the high cost of expert testimony presents a unique challenge for indigent defendants, who comprise the majority of those arrested on the basis of positive eyewitness identifications (NRE, 2017; Proctor, Semega, & Kollar, 2015). Finally, expert testimony may result in additional delays given that judges must appraise experts' methodological validity per the *Daubert* standard through a review of experts' supporting scientific research (Sheehan, 2011).

Overall, although a series of safeguards exist to moderate eyewitness error, the majority of these are ineffective. Regrettably, many of the safeguards are unsuccessful because they necessitate adequate knowledge of eyewitness factors (e.g., presence-of-counsel, motion-to-suppress, juror instructions, cross-examination), which appears to be variable amongst attorneys, judges, and jurors. Another common issue is the lack of consistency in implementing these safeguards across courts. For example, not all safeguards are permitted or required in all jurisdictions (e.g., juror instructions, expert testimony), which is concerning considering that none are entirely fail-safe. Ultimately, given the limitations of traditional safeguards and the continued reliance on eyewitness testimony, the judicial system must focus on improving procedures for collecting eyewitness evidence, reducing the necessity for judges and jurors to be educated on the limitations of eyewitness testimony. However, careful examination of those variables influencing eyewitness accuracy that are outside of well-designed eyewitness evidence collection procedures may further inform judges and jurors of the reliability of eyewitness accounts.

System and Estimator Variables

Over the last several decades, researchers have identified numerous factors that influence the accuracy of eyewitness testimony. To enhance the utility and application of these factors within the criminal justice system, researchers now characterize them as either system or estimator variables, though some variables may be classified under both categories. Wells (1978) defined system variables as those subject to judicial manipulation, such as interview and lineup identification procedures, whereas estimator variables are unique to a given crime and outside the control of court officials (e.g., witness viewing conditions, presence of a weapon, witness characteristics, etc.; Wells, 1978). Although estimator variables are of great significance when scientifically evaluating eyewitness credibility, researchers often prioritize the investigation of system variables due to their potential to systematically reduce or prevent eyewitness error (Wells, 1978).

System variables.

Retention interval.

Time. In the context of eyewitness research, retention intervals represent the length of time between the witnessing of a criminal event (the encoding and storage phase of memory) and the eyewitness recollection of event details or identification of the suspect (the retrieval phase of memory; Wells, 1978). Retention intervals should be considered in the context of eyewitness memory given the adverse effects of time (i.e., natural decay, retroactive interference) on memory accuracy. Consistently, eyewitness research suggests that greater interview delays result in poorer eyewitness recall for both event details and suspect identifications (Odinot, Wolters, & van Giezen, 2013; Sauer, Brewer, Zweck, & Weber, 2010; Tuckey & Brewer, 2003). Unfortunately, the effects of retention intervals on memory in the real world are less straightforward due to case factors (e.g., police may not identify a plausible suspect for months, in which case time may be considered an estimator variable influencing eyewitness identifications), the potential for uncontrolled rehearsal, differences in retrieval methods, and a variety of other estimator variables (e.g., viewing conditions, attention, length of exposure, etc.; National Research Council [NRC], 2014; Read & Connolly, 2007). Nevertheless, it is generally agreed that law enforcement should obtain eyewitness statements or identifications (when possible) in a timely manner to reduce the effects of time and intervening events on memory accuracy (NRC, 2014; Read & Connolly, 2007; Technical Working Group on Eyewitness Evidence [TWGEE], 2003).

Multiple recollections. Multiple recollections of event details across retention intervals may also negatively influence eyewitness reliability (Read & Connolly, 2007). Specifically, witnesses may be asked to recall an event multiple times across various pretrial procedures (e.g., the initial police interview, deposition, affidavit, or examination for discovery [during which a witness may be asked to make an oral testimony under oath for use during trial]) and trial testimony (Read & Connolly, 2007). Research addressing the effects of repeat testing suggests that eyewitness accuracy for event details is relatively stable across recollections, despite increased inconsistencies (e.g., contradictions or variation in detail quantity; Gilbert & Fisher, 2006; Odinot et al., 2013). Unfortunately, jurors may use inconsistencies as an indicator of eyewitness inaccuracy, despite the fact that there is a weak relationship between the two (Gilbert & Fisher, 2006; Oeberst, 2011). To remedy issues associated with multiple recollections, judges should educate jurors on the relationship between inconsistencies and witness accuracy and investigators should both limit the amount of repeat testing and the intervals between repeat testing to reduce forgetting or contamination (Read & Connolly, 2007).

Eyewitness interview.

Interview approach and structure. Interview approach and question structure may also impact eyewitness accuracy (Wells, 1978). Researchers developed the Cognitive Interview (CI) in response to such concerns, which has since gained considerable support in the realm of eyewitness interviewing (Fisher & Geiselman, 1992; Fisher & Schreiber Compo, 2007). This approach recommends that interviews begin with rapport building and a description of interview expectations (Fisher & Schreiber Compo, 2007). The introduction is followed with open-ended questions, probing (which involves follow-up questions and mental imagery), a review of information, and closing procedures (e.g., collecting witness information and offering extended contact). With regard to questioning, open-ended questions (e.g., "Describe everything that happened") enable witnesses to freely discuss an event in an unrestricted manner, whereas closed-questions elicit a direct response and limit the amount of information provided (TWGEE, 2003). Non-leading closed-ended questions such as, "What color was the suspect's shirt?" are preferred over leading closed-questions such as, "Was the suspect's shirt blue?"

Despite ample empirical support for the CI approach (Memon, Meissner, & Fraser, 2010), police officers do not consistently follow the recommended procedures. For instance, one study found that investigators in South Florida tended to use counterproductive interviewing techniques (e.g., using complex questions or interrupting the witness) as opposed to productive techniques derived from CI (e.g., context reinstatement or rapport building; Schreiber Compo, Gregory, & Fisher, 2012). Procedural inconsistencies were also found in officers from Canada (Snook & Keating, 2011) and the United Kingdom (Dando, Wilcock, & Milne, 2008). However, in a separate study assessing police agencies across the U.S., officers self-reported using productive techniques more often than counterproductive techniques and rated productive techniques as more likely to elicit accurate information (Mueller, Schreiber Compo, Molina, Byron, & Pimentel, 2015). Although this is promising, further research is needed to determine whether members of law enforcement actually use the techniques they report using (Mueller et al., 2015).

Suggestive interrogation. In their pioneering research, Loftus and Palmer (1974) demonstrated that alterations in the phrasing of interrogative questions readily introduces false memories in participants' recollections, also known as the misinformation effect (Loftus & Palmer, 1974). Researchers continue to find evidence for the misinformation effect (Foster, Huthwaite, Yesberg, Garry, & Loftus, 2012), even for highly memorable negative events (Paz-Alonso, Goodman, & Ibabe, 2013) and for nonverbal misinformation (Gurney, Pine, & Wiseman, 2013). Further, memory remains susceptible to misinformation, even when individuals are given the opportunity to recall event details prior to being exposed to misleading information (Chan, Thomas, & Bulevich, 2009). Unfortunately, suggestive questioning is commonly employed during forensic interviews, and may lead to the misinformation effect (Eisen, Gomes, Lorber, Perez, & Uchishiba, 2013). As a result, law enforcement officers should receive training on proper interviewing techniques to reduce unduly suggestive procedures (TWGEE, 2003).

Suspect imagery. During the interrogation process, witnesses sometimes participate in the creation of a suspect composite, or facial impression derived from witness descriptions (Davies & Valentine, 2007; Wells, 1978). Although there is little research on the effects of composite drawings on recognition memory, several studies found that composite creations increase lineup identification errors (Kempen & Tredoux, 2012; Wells, Charman, & Olson, 2008). Unfortunately, because composites are sometimes necessary to make an arrest, it may be unreasonable to eliminate this procedure entirely (Kempen & Tredoux, 2012). Thus, further research is needed to clarify the usefulness and necessity of composites until more effective arrest tactics are available.

Mug books, or books containing photos of suspects with prior arrests, are also used when law enforcement officers have yet to arrest a suspect (McAllister, 2007). Two meta-analyses on the effects of mugshots found that mugshot exposure is detrimental to lineup identification performance (Deffenbacher, Bornstein, & Penrod, 2006; Goodsell, Neuschatz, & Gronlund, 2009). In particular, mugshot exposure increases participants' false alarms and decreases their proportion of correct responses (Deffenbacher et al., 2006). Such performance may be due to the commitment effect, or the tendency to make a lineup selection based on an earlier mugshot selection regardless of accuracy (Deffenbacher et al., 2006; Goodsell et al., 2009). As a result, it is recommended that lineups not be administered to witnesses who have made a mug book selection (Goodsell et al., 2009).

Eyewitness lineup identification. When an individual reportedly witnesses a culprit committing a criminal act, they will likely be shown a live or photo lineup to identify the suspect (Wells et al., 2006). If a positive identification of the suspect is made (regardless of whether they are the actual culprit), it will become one of the most powerful pieces of evidence suggestive of their guilt (Clark, Moreland, & Gronlund, 2014; Smalarz & Wells, 2012). Thus, validated lineup procedures are needed to reduce the likelihood of eyewitness error (e.g., identification of an innocent suspect, identification of a filler, or incorrect rejection of the lineup) and ultimately, wrongful convictions (Clark et al., 2014).

Suspect presentation. There are several suspect identification methods for law enforcement to choose from. At the most general level, law enforcement must first determine whether they will present a showup or a lineup. A showup is when the suspect alone is presented to the witness (Wells et al., 2000). This procedure is usually implemented if a suspect is detained shortly after the commission of a crime in the general vicinity of the crime (Wells et al., 2000; Garrett, 2011). Although showups are commonly used (61.8% of agencies; Police Executive Research Forum [PERF] & NIJ, 2013), they are not recommended due to their suggestive nature and poor reliability (Garrett, 2011; Gronlund et al., 2012). Traditionally, lineups consist of the suspect and five fillers (known innocent individuals, sometimes referred to as foils or distractors), which are meant to protect suspects from unreliable eyewitnesses (Gronlund et al., 2012; Wells & Olson, 2003). Photographic lineups are currently the most common identification procedure (94.1% of agencies), although they can also be conducted live (PERF & NIJ, 2013).

Lineup composition. When constructing a photographic lineup, there are several conventions to follow. First, only one suspect should be placed in the lineup, as the chances of identifying an innocent suspect will increase with a reduced number of fillers (Wise, Cushman, & Safer, 2012). Generally, it is recommended that no fewer than five fillers are selected for the lineup (Malpass, Tredoux, & McQuiston-Surret, 2007), with five fillers being the trend in law enforcement (82.6% of agencies; PERF & NIJ, 2013). The process of selecting fillers is a delicate one, as careless selection may bias the lineup toward selection of the suspect, who may in fact be innocent (Clark et al., 2014; Colloff, Wade, & Strange, 2016). To construct a fair lineup, fillers should match witnesses' description of the culprit, with each being generally equal with regard to their plausibility (Malpass et al., 2007). Fillers may also be selected on the basis of visual similarity to the suspect.

Although it is recommended that fillers be selected on the basis of witness descriptions rather than suspect similarity (TWGEE, 2003), the literature regarding this issue is mixed. Some argue that matching-to-description is preferred because this will produce a lineup where all members correspond with the witness's memory, reducing bias toward the suspect (Luus & Wells, 1991). At the same time, this method should facilitate culprit recognition by enabling the right amount of facial variation across lineup members, whereas match-to-appearance may be impairing due to significant facial homogeneity (Luus & Wells, 1991). Some evidence supports the superiority of the match-to-description method (Wells, Rydell, & Seelau, 1993); however, other evidence supports the match-to-appearance method

(Lindsay, Martin, & Webbter, 1994). Nevertheless, more recent literature suggests that neither method is superior with regard to improving eyewitness performance (Darling, Valentine, & Memon, 2008).

Clearly, more research must be done to determine the effects of filler selection on eyewitness identification accuracy. However, the fairness of lineups can be further promoted through assessment of the functional size and effective size, which should be distinguished from nominal size, or the number of individuals in the lineup (Malpass, 1981; Wells, Leippe, & Ostrom, 1979). A lineup's functional size, or degree of bias, is calculated 'by taking the reciprocal of the proportion of "mock witnesses" who choose the suspect from the lineup' (Smalarz & Wells, 2012, p. 4). For example, if 30 of 60 mock witnesses identified the suspect in a six-person lineup, the reciprocal 60/30 would result in a functional size of 2.0, suggesting that the lineup contains only two viable fillers (Smalarz & Wells, 2012). Alternatively, effective size provides an estimate of viable lineup members, though the calculation is more complex (Malpass et al., 2007). Ultimately, these methods, among others, are useful for systematically evaluating lineup fairness (Malpass et al., 2007).

Lineup presentation. Researchers have long sought to distinguish rates of accuracy between simultaneous and sequential lineup presentations (e.g., Wells et al., 1998). Simultaneous lineups, or lineups in which the witness views all photographs at once, are the most common administration procedure in law enforcement (68% of agencies; PERF & NIJ, 2013). Conversely, the sequential method involves showing the witness one lineup photo at a time. This procedure requires a decision regarding each photo prior to viewing the next photo. Although the NIJ guide for eyewitness procedures does not report a lineup presentation preference (TWGEE, 1999), researchers recommend the sequential method (Wise et al., 2012).

Researchers tend to prefer the sequential method because it prevents witnesses from using a relative-judgment process when making an identification from a lineup (Smalarz & Wells, 2012). The relative judgment theory holds that witnesses are inclined to select whoever is most similar to the culprit relative to the other lineup members (Wells, 1984), increasing the risk of an identification when the culprit is absent from the lineup (Smalarz & Wells, 2012). Alternatively, the sequential method requires the witness to compare each photo to their memory of the culprit without influence from the other photos (Smalarz & Wells, 2012). This process is believed to result in a more conservative culprit selection, potentially leading to the rejection of the lineup when the culprit is, in fact, present (Palmer & Brewer, 2012). Unfortunately, this cost-benefit balance makes it difficult to determine which method is superior (Clark, 2012). A recent meta-analysis illustrates this issue in finding that correct identifications were slightly more likely with the simultaneous method (r = -.08), though the sequential method reduced error in culprit-absent lineups (r = .22; Steblay, Dysart, & Wells, 2011). Research published since the meta-analysis is generally consistent with these findings (Dobolyi & Dodson, 2013; Gronlund et al., 2012; Mickes, Flowe, & Wixted, 2012; Wells, Steblay & Dysart, 2015).

Blind administration. Experts generally recommend that police use a double-blind procedure when administering lineups (Wells, 1988), a method suggested to reduce bias in research (Goodwin, 2010). In research, a double-blind procedure is one in which the experimenter and participant are unaware of the assigned condition (Goodwin, 2010). When applied to lineup administration, a double-blind procedure is one in which the administrator and the witness are both unaware of which lineup member is the suspect (Wells, Steblay, & Dysart, 2012).

A double-blind procedure minimizes the likelihood of experimenter-expectancy effects (Rosenthal, 1966). The experimenter-expectancy effect occurs when experimenters (or police conducting lineups) communicate their expectations through subtle mannerisms (e.g., body language, verbal reinforcement; Rosenthal & Fode, 1963). This may alter participant behaviors, producing results that confirm experimenters' hypotheses. Expectancy effects are illustrated in lineup identification research, which found that single-blind administration (in which the administrator is not blind) increased the number of suspect identifications, suggestive of administrator bias (Greathouse & Kovera, 2009). Non-blind administrators may also bias witness confidence (Wells & Bradfield, 1998; Garrioch & Brimacombe, 2001; Rodriguez & Berry, 2010), produce biased records of the lineup procedure (e.g., recording, "he looks most like the culprit" as a positive identification; Rodriguez & Berry, 2012; Steblay, 2011), and lead to less effective eyewitness interviews (Rivard, Pena, & Schreiber Compo, 2015). As a result, double-blind administration remains a staple recommendation (Wells et al., 2012).

Although double-blind procedures are preferred for lineup identification tasks, they are not a required standard due to the potential for staff shortages that may render this method impractical (TWGEE, 1999). This is reflected in current practices in which the majority of photo lineups are administered in a non-blind manner (69% of agencies; PERF & NIJ, 2013). Still, it is highly recommended that double-blind administration be used whenever possible (Wells et al., 2012).

Lineup instructions. When conducting lineups, it is essential that administrators provide unbiased instructions to preclude suggestive identifications (Wells et al., 2012). Notably, lineups carry the assumption that the individual who is believed to be the culprit will be present, increasing the likelihood that a witness will select someone (TWGEE, 2003). Thus, unbiased instructions should state that the culprit may or may not be present in the lineup, allowing a "not present" response (Smalarz & Wells, 2015; TGWEE, 1999). Alternatively, biased instructions may suggest or state that the culprit is present in the lineup (Clark, 2012). Research investigating biased instructions has found that they may reduce witnesses' decision criterion, which may lead to guess responding (Clark, 2005; Greathouse & Kovera, 2009). Ultimately, because suspects may appear in a lineup based on a hunch alone, unbiased instructions are a necessary procedure for protecting the innocent (Wells et al., 2012).

Post-identification feedback. Lineup administrators may contaminate eyewitness reports even after they've selected an individual from a lineup. For example, post-identification feedback alluding to the accuracy of a lineup selection may inflate witnesses' retrospective certainty and recollection of event details (e.g., quality of view, attention, exposure to facial features, etc.; Wells & Bradfield, 1998). A meta-analysis summarizing 15 years of research provides further evidence for the inflating effects of confirmatory feedback on retrospective judgments, especially for mistaken witnesses (Steblay, Wells, & Douglass, 2014). Post-identification feedback may also impair an evaluator's ability to distinguish between accurate and mistaken identifications (Smalarz & Wells, 2014). As a result, post-identification feedback should be precluded through the use of double-blind lineup administration (Dysart, Lawson, &

Rainey, 2012). However, because post-identification feedback may occur in other forms (e.g., being called to testify, co-witness contamination, etc.; Smalarz & Wells, 2015), officers should obtain statements regarding confidence and quality of memory at the time of the identification (Wells et al., 2012).

Overall, there are a large number of system variables for law enforcement to consider when preparing to interact with, interview, and test eyewitnesses. Most of those variables concern the lineup identification task (e.g., suspect presentation, lineup composition, lineup presentation, blind administration, lineup instructions, and post-identification feedback). Regrettably, lineup identifications carry a significant amount of weight when presented in court, despite ample opportunity for suggestive, biased procedures (Clark et al., 2014; Smalarz & Wells, 2012). Thus, continued investigation into the factors that influence eyewitness lineup identification performance is essential to improve accuracy, thereby reducing the number of wrongful convictions.

Estimator variables. As mentioned previously, estimator variables are those factors outside the control of the criminal justice system (Wells, 1978). As such, their effect on a given case can only be estimated (Wells et al., 2006). Therefore, research addressing estimator variables will not lead to systematic improvements in eyewitness accuracy; however, this research is essential for distinguishing between accurate and inaccurate eyewitnesses (Wells & Olson, 2003). Although there are countless estimator variables, the following section will focus on those most relevant to the present research and those that have received significant attention in the literature.

Event characteristics.

View of the culprit. Memory for a culprit's appearance depends on a variety of event characteristics, such as lighting conditions, clarity of the culprit's features, physical distance from the culprit, exposure duration, and anything that might obstruct one's view or alter visibility conditions (NRC, 2014). As would be expected, longer exposure durations increase facial identification accuracy (e.g., higher correct identifications and lower rates of false alarms) relative to shorter durations (Bornstein, Deffenbacher, Penrod, & McGorty, 2012). However, one study showed that exposure duration interacts with confidence-accuracy relationships, such that shorter exposure duration led to overconfidence for accurate identifications, where overconfidence represents the degree to which average confidence outweighs overall accuracy (Palmer, Brewer, Weber, & Nagesh, 2013). Alternatively, lower levels of confidence corresponded with reduced accuracy, particularly amongst "choosers," or those who made a lineup identification, relative to non-choosers, or those who did not make a lineup identification (Palmer, Brewer et al., 2013). Still, the proportion of correct positive identifications remained higher for those with longer exposure durations (Palmer, Brewer, et al., 2013). Thus, exposure duration may be an important factor when assessing eyewitness accuracy.

Weapon. A large body of research is devoted to evaluating the weapon focus effect, which holds that the presence of a weapon may diminish eyewitness memory due to a diversion of attention (Fawcett, Russell, Peace, & Christie, 2013; Loftus, 1979). Presently, there are two hypotheses underlying the weapon focus effect: the arousal/threat hypothesis and the unusual item hypothesis (Fawcett et al., 2013). The former suggests that reduced quality of memory is the product of physiological or emotional arousal, which leads to increased focus on central cues (i.e., a weapon) rather than peripheral cues (i.e., culprit details; Easterbrook, 1959; Fawcett et al., 2013). Conversely, the latter hypothesis suggests that attentional narrowing is the product of object unusualness (Antes, 1974; Fawcett et al., 2013). Unfortunately, the function of these two mechanisms will inevitably vary according to the method of weapon exposure, which differs across the literature (e.g., laboratory studies, simulation studies, or actual crimes; Fawcett et al., 2013).

Laboratory research assessing the weapon focus effect has found increased time spent looking at weapons rather than faces (Biggs, Brockmole, & Witt, 2013), reduced recognition accuracy when accounting for confidence (Hope & Wright, 2007), increased false positives in target-absent lineups (Erickson, Lampinen, & Leding, 2014), increased susceptibility to misinformation (Saunders, 2009), and poorer descriptions and memory for female culprits (Pickel, 2009). The weapon focus effect has also been observed in simulated events (Pickel, Ross, & Truelove, 2006) and virtual environments (Kim, Park, & Lee, 2014). Although research generally supports the presence of a weapon focus effect (Fawcet et al., 2013), a more recent meta-analysis found no effect of weapon on correct identifications across target-present and target-absent lineups (Kocab & Sporer, 2016). However, weapon focus did have a significant effect on accuracy of target descriptions (Kocab & Sporer, 2016). Given the effect of a weapon on descriptive accuracy, researchers must consider the weapon focus effect when evaluating eyewitness credibility, notwithstanding aggregate findings that failed to find effect of a weapon on lineup identification.

Testimony characteristics. Testimony characteristics also provide useful information pertaining to eyewitness credibility; however, unlike traditional estimator variables, these factors do not causally influence accuracy (Wells et al., 2006). Rather, due to their correlational nature, testimony characteristics can be used postdict, or estimate, the accuracy of eyewitnesses after a lineup identification is made (Wells et al., 2006).

Witness confidence and certainty. Obtaining a statement of witness certainty or confidence following both lineup identifications and non-identifications is a recommended procedure in law enforcement (TWGEE, 2003). As mentioned previously, the statement should be obtained immediately after the identification due to the malleability of confidence over time (Steblay et al., 2014; Wells et al., 2012). This is generally reflected in practice, such that 76.2% of agencies using photo lineups request a statement of certainty for identifications, though only 43.9% request certainty for non-identifications (PERF & NIJ, 2013). Presently, most agencies collect statements of certainty using witnesses' own words, which may be supplemented with a number or percentage (PERF & NIJ, 2013).

A measure of witness confidence is crucial given that it may serve as a postdictor of witness accuracy (Wells et al., 2006). However, the notion that witness confidence is suggestive of witness accuracy is a complicated one, fraught with conflicting evidence. A meta-analysis from more than two decades ago suggests that the correlation between confidence and accuracy is generally weak (r = .29); however, the correlation was consistently and reliably higher for those who made a lineup identification relative to those who did not (r = .41 and r = .12, respectively; Sporer et al., 1995). Although a medium correlation is not encouraging considering the real-world stakes associated with inaccurate lineup identifications, these findings must be interpreted with caution given that point-biserial correlations may underestimate confidence accuracy relationships (Juslin, Olsson, & Winman, 1996; Wixted, Mickes, Clark, Gronlund, & Roediger, 2015).

Given problems with point-biserial correlations, Juslin et al. (1996) suggest that confidence-accuracy relationships be assessed using calibration analyses and indices of diagnosticity. Calibration examines the realism of confidence through comparison of subjective and objective probabilities (Juslin et al., 1996). With this method, witness confidence is assessed on a percentage scale (i.e., 0%, 10%...100% confident) and compared to the frequency of accurate identifications within the corresponding category of confidence. Witnesses whose subjective level of confidence agree with percentages of accuracy (e.g., witnesses who express 90% confidence and are accurate 90% of the time) are deemed "well-calibrated" (Juslin et al., 1996, p. 1305; Wixted et al., 2015). On the other hand, the diagnosticity ratio uses a Bayesian approach to calculate the ratio of accurate to inaccurate lineup identification decisions obtained under certain conditions (Wells & Lindsay, 1980).

Researchers implementing measures of calibration and diagnosticity have found a significant relationship between confidence and accuracy, such that high levels of confidence are associated with greater identification accuracy and low levels of confidence are associated with reduced accuracy (Horry, Palmer, & Brewer, 2012; Palmer, Brewer, et al., 2013; Sauer et al., 2010). Some have also found non-choosers to be well-calibrated (Sauerland, Sagana, & Sporer, 2012). Although this paints an optimistic picture for the confidence-accuracy relationship, these findings do not translate to one's level of confidence expressed well after the original identification (e.g., when testifying; Wixted et al., 2015). Thus, it is suggested that jurors consider confidence ratings from the time of the original identification when weighing evidence in trial (Wixted et al., 2015). Although in the past researchers recommended that confidence be interpreted with caution (e.g., Wells, Olson, & Charman, 2002), preliminary research suggests that eyewitness confidence does not unduly influence mock-jurors' decision-making (Wykes, 2014), which may ease policy-makers' concern regarding the possibility of wrongful conviction.

Speed of lineup identification. The notion that response latency, or the speed at which an identification is made, may be an indicator of memory strength was introduced in early research assessing recognition memory (e.g., Baddeley & Ecob, 1973; Murdock & Dufty, 1972). Given the clear applicability of memory research to the field of eyewitness testimony, it makes intuitive sense that response latency would be investigated in the eyewitness literature. However, prior to the Deputy Attorney General's recent memorandum for eyewitness identification procedures, law enforcement officers were not required to document lineup identification response speed (Department of Justice [DOJ] & Office of the Deputy Attorney General, 2017); thus, research regarding this variable is somewhat scarce. Still, there is evidence that faster identifications are associated with greater accuracy than slower identifications (Brewer, Caon, Todd, & Weber, 2006; Sauerland & Sporer, 2009). In addition, slower identifications may lead to lower ratings of witness credibility and defendant guilt relative to fast identifications (Neal, Christiansen, Bornstein & Robicheaux, 2012). Thus, response latency may be a useful measure of eyewitness accuracy and credibility.

Witness characteristics.

*Demographics***.** As one might expect, there are a variety of demographic characteristics that may influence witness accuracy. Again, these factors are outside the control of the criminal justice system, and their effect on witness accuracy can be estimated, but will vary in individual cases.

The effect of race on facial recognition has captivated researchers for more than a century with its surprising degree of consistency (Brigham, Bennett, Meissner, & Mitchell, 2007; Chance & Goldstein, 1996; Feingold, 1914). The own-race bias, otherwise known as the cross-race effect or other-race effect, suggests that facial recognition for one's own race is superior to facial recognition for another race (Brigham et al., 2007). Consequently, witnesses may have difficulty discriminating and accurately identifying a culprit of a different race (Malpass & Kravitz, 1969; NRC, 2014). The effects of race on eyewitness identification accuracy are illustrated in the real world; for example, 53% of exonerated sexual assault cases involving erroneous eyewitness identifications concerned black defendants and white victims (Gross & Shaffer, 2012).

A number of research studies also provide evidence for the own-race bias. For example, an early meta-analysis involving 91 independent samples found a greater proportion of accurate identifications (or "hits") and a lower proportion of false alarms for own-race faces compared to other-race faces (Meissner & Brigham, 2001). Recent literature also suggests cross-race effects are more pronounced with reduced exposure time and longer retention intervals (Marcon, Meissner, Frueh, Susa, & MacLin, 2010), which may impair the encoding efforts necessary for other-race faces (Goldinger, He, & Papesh, 2009). Further, group presentation of other-race faces produces greater memory impairments compared to individual presentation (Pezdek, O'Brien, & Wasson, 2012), and the provision of contextual information at the time of identification does not improve accuracy (Evans, Marcon, & Meissner, 2009). Given the consistent findings across studies, the other-race bias is a widely accepted phenomenon in the eyewitness literature.

Age also plays a significant role in the literature on eyewitness accuracy, particularly with regard to child and older adult witnesses (Garrett, 2011; Memon, Gabbert, & Hope, 2013). In general, research demonstrates poorer facial recognition in children (Karageorge & Zajac, 2011) and in adults over the age of 60 (Firestone, Turk-Browne, & Ryan, 2007). However, full exploration of this issue is beyond the scope of this dissertation due to the varying cognitive mechanisms that may be at work in these age groups, which may differentially interact with the variables presented earlier (Beaudry & Bullard, 2014). Thus, this section will focus on the own-age bias, or superior facial recognition for one's own age group (Rhodes & Anastasi, 2012). A recent meta-analysis evaluating own-age bias in the context of facial recognition found a greater proportion of accurate identifications and lower proportion of false alarms for same-age faces relative to other-age faces (Rhodes & Anastasi, 2012). Discriminability was also superior when viewing same-age faces for all age groups (e.g., children, young adults, older adults; Rhodes & Anastasi, 2012).

Similarly, research addressing the effects of gender on identification accuracy has focused on own-gender bias, which suggests superior facial recognition for one's own gender (Sporer, 2001). A recent meta-analysis investigating the matter found an overall own-gender bias for females, though males did not demonstrate an own-gender bias (Herlitz & Lovén, 2013). Of note, females remembered more faces than males in general, suggesting that females may have superior facial processing abilities (Herlitz & Lovén, 2013). In sum, research addressing own-age, own-race, and own-gender bias suggests that memory is better when witness and culprit demographics are congruent (Rhodes & Anastasi, 2012). Ultimately, this may be the product of perceptual expertise, or the notion that individuals develop an expertise for processing the faces of those they spend the most time with, which are typically individuals with similar demographics (Rhodes, Brake, Taylor, & Tan, 1989).

Intoxication. Of growing interest in the eyewitness literature are the effects of intoxication on eyewitness performance. This interest corresponds with the likelihood that witnesses are intoxicated at the time of a crime (Palmer, Flowe, et al., 2013). A survey of law enforcement officers illustrates this issue in finding that intoxicated witnesses are common or very common (52.9% and 20.2%, respectively; Evans et al., 2009). Further, intoxicated witnesses are equally as likely as sober witnesses to supply police with a culprit description and to participate in lineup identification tasks (Palmer, Flowe, et al., 2013). Given the prevalence of intoxicated witnesses and their contribution to criminal investigations, it is essential to understand the ways in which various substances might impact eyewitness accuracy.

Recently, eyewitness researchers have focused their efforts on understanding the effects of alcohol on witness memory. This is primarily due to the sizeable proportion of intoxicated witnesses under the influence of alcohol (73%) relative to other drugs (Palmer, Flowe, et al., 2013). Further, the physiological (e.g., alterations in perception, cognition, behavior) and psychological effects (e.g., dependence, heightened emotion) of alcohol are well documented and produce cause for concern (World Health Organization [WHO], 2014). Concern regarding alcohol-intoxicated witnesses translates to jurors' perceptions, such that these witnesses may be viewed as more impaired and less credible with regard to their lineup identification performance (Evans & Schreiber Compo, 2010).

Although the specific effects of alcohol may vary across consumers (Holdstock & de Wit, 1998), the notion that alcohol impairs memory performance is generally accepted (Acheson, Stein, & Swartzwelder, 1998; Oslin, 2003; Schweizer et al., 2006; White, 2003). This is particularly true for the encoding of episodic memories (Mintzer, 2007) and the formation of long-term memories (White, 2003) due to the influence of alcohol on NMDA receptors found in in the hippocampus, which is responsible for encoding new memories (Chandrasekar, 2013). Thus, alcohol can be expected to impact the recollection of a crime. For example, mock witnesses with higher levels of intoxication recalled fewer details of a crime relative to those with lower levels of intoxication (Hagsand et al., 2013a). However, the accuracy of details was unaffected (Hagsand et al., 2013a). Though some researchers have replicated these findings (Crossland, Kneller, & Wilcock, 2016), others did not identify differences in recall between intoxicated and sober witnesses (Schreiber Compo, Evans, Carol, Villalba, et al., 2011). Further, lineup identification accuracy is comparable between intoxicated and sober witnesses (Hagsand et al., 2013b; Harvey, Kneller, & Campbell, 2013b; Kneller & Harvey, 2016; except Dysart, Lindsay, MacDonald, & Wicke, 2002). Intoxicated and sober witnesses also demonstrate similar levels of confidence and response latencies when making identifications (Kneller & Harvey, 2016).

In addition, researchers have identified variations in intoxicated-witness memory for peripheral and central details. For example, in support of the Alcohol Myopia Theory, researchers found that witnesses under the influence of alcohol recalled fewer accurate peripheral details compared to sober witnesses, though memory for central details was comparable (Schreiber Compo, Evans, Carol, Kemp, et al., 2011; Steele & Josephs, 1990). Similarly, Bayless and Harvey (2016) found that intoxicated witnesses had greater accuracy for central aspects of a task, with reduced accuracy for the peripheral aspects. Further, when tracking eye movements, alcohol-intoxicated witnesses primarily focused on central details of a scene, diminishing overall recall accuracy (Harvey et al., 2013a). Further research addressing this issue is necessary to determine the conditions in which alcohol-intoxicated witnesses are less reliable given mixed findings to date.

As mentioned at the beginning of this review, there are only two published studies investigating the effects of cannabis on eyewitness accuracy (Vredeveldt et al., 2018; Yuille et al., 1998). Vredeveldt and colleagues (2018) recruited participants as they entered and exited one of four coffee shops in Amsterdam with the expectation that those entering the coffee shop were sober and those exiting were under the influence of cannabis. The researchers showed willing participants a two-minute video depicting an armed robbery at a convenience store. They then completed a two-minute Sudoku filler task, followed by an open-ended free-recall and cued-recall interview. Participants were then shown 1 of 12 target-present or target-absent simultaneous lineups (six of which were target-present and six of which were target-absent) and were asked to rate their confidence in their selection. At the conclusion of the study, participants were asked to answer demographic questions, estimate the amount of cannabis (or other substances) consumed that day (number of grams or joints), and rate their subjective level of intoxication.

Results revealed that cannabis-intoxicated witnesses recalled significantly fewer accurate details of the event relative to sober witnesses, particularly for details pertaining to persons and surroundings, but not actions or objects. There was no significant association between self-reported cannabis dose or subjective intoxication ratings and accuracy of details recalled. Alternatively, intoxicated witnesses and sober witnesses did not differ with regard to the number of inaccurate details recalled, and there was no significant association between self-reported cannabis dose or subjective intoxication ratings and number of inaccurate details. There was no significant effect of cannabis intoxication on users' distribution of responses (i.e., true positive, false positive, or "not there" response) in the target-present or absent lineup conditions. This finding suggests that cannabis intoxication neither reduced correct identifications nor increased false alarms. Moreover, after collapsing target-present and absent conditions, the researchers failed to find a significant effect of cannabis intoxication on lineup identification accuracy. In addition, cannabis did not have a dose-dependent effect on lineup identification accuracy. With regard to confidence ratings, there was a significant interaction between cannabis and identification accuracy, such that accurate intoxicated witnesses were significantly more confident than accurate sober participants in target-present conditions, though confidence did not differ among inaccurate intoxicated and sober witnesses. There was no effect of cannabis or accuracy on confidence ratings in target-absent lineups. Finally, the researchers examined confidence-accuracy correlations across intoxicated and sober witnesses for choosers and non-choosers. There was no significant confidence-accuracy correlation among intoxicated and sober non-choosers. Although there was no significant confidence-accuracy correlation among sober choosers, a significant positive correlation emerged among intoxicated choosers. The researchers concluded that, because the two correlations differed significantly, intoxicated choosers were significantly better than sober choosers at judging the accuracy of their lineup selection. When taken together, these findings suggest that although cannabis users demonstrate impaired recall memory, their lineup identification, or recognition, performance remains comparable to sober witnesses.

In Yuille and colleagues' (1998) study, participants consumed either a cannabis or placebo cigarette prior to witnessing a staged event that involved an argument between the experimenter and a confederate (or actor) regarding the odor of cannabis. However, participants were unaware that they would be witnessing this event and instead were told that they would be performing a memory task. After the event, the experimenter informed participants that the event was staged and subsequently collected ratings of anxiety as well as a statement regarding their memory for the event. Participants returned one week later to provide an additional statement and to view an eight-person simultaneous photospread that contained either the target or a replacement filler.

Results confirmed that witnesses who received a cannabis cigarette were significantly more intoxicated than those who received a placebo cigarette, as evidenced by the Marijuana Effect Scale. In addition, both experimental and control participants retrospectively reported higher anxiety during the staged event than after the event. Intoxicated participants recalled significantly fewer details of the staged event immediately following the incident in comparison to those who received a placebo, though these differences disappeared when questioned a week later. Moreover, groups were similar with regard to the accuracy of details recalled, lineup identification accuracy, and their degree of confidence. Although these findings demonstrate a temporary effect of cannabis on eyewitness memory, further research is needed to identify additional conditions in which cannabis may impact witness reliability (Yuille et al., 1998).

Cannabis

Policy makers and researchers have shown interest in the effects of cannabis for nearly a century (Baron, 2015). Given that this span of interest overlaps with early investigations into eyewitness accuracy (e.g., Münsterberg, 1908), it is surprising that so few researchers are drawn to the intersection of such concerns. One explanation for the lack of attention toward the effects of cannabis on eyewitness accuracy may be the complex legislation associated with the drug. In particular, although advances are being made with regard to the legalization of cannabis, the production, possession, and consumption of this plant remains federally illegal under the Controlled Substances Act of 1970 (Baron, 2015; Madras, 2015). Nearly 50 years ago, this federal statute classified cannabis as a Schedule I substance, suggesting no known medical uses and a high potential for abuse (Controlled Substances Act, 1970). As a result, researchers are generally prohibited from investigating the potential harms and benefits of cannabis (Baron, 2015).

Despite the federal restrictions placed on cannabis in 1970, cannabis-related research continues to advance amid changes in state legislation. Notably, a total of ten states and Washington D.C. now allow adult recreational cannabis use, and a total of 34 states have enacted laws allowing cannabis for medicinal purposes (NCSL, 2019a; 2019b). These legislative changes may have contributed to a rise in cannabis users from 2002 to 2014 (from 6.2% to 8.4% of the population), for a total of 22.2 million past-month users aged 12 or older (CBHSQ, 2015). However, prevalence rates are notably higher in states that have legalized recreational cannabis use (e.g., 31% among young adults in Colorado; United Nations Office on Drugs and Crime [UNODC], 2016). Cannabis use is also at an all-time high across the globe, with 182.5 million users (UNODC, 2016). Given the remarkable prevalence of cannabis and ongoing legislative changes, the number of cannabis-user eyewitnesses will inevitably rise. Thus, further research investigating the effects of cannabis on eyewitness accuracy is essential.

A Brief Introduction to Cannabis

Prior to exploring the potential effects of cannabis on eyewitness accuracy, a brief introduction to the plant's taxonomy, constituents, and common uses is provided. In general, the plant genus *Cannabis* comprises three commonly accepted species, including *Cannabis sativa, indica,* and *ruderalis,* which are differentiated according to their biochemical constituents (Baron, 2015; Hillig & Mahlberg, 2004). Strains of species containing high concentrations of the psychoactive cannabinoid, delta^{9}-

tetrahydrocannabinol (THC), are often referred to as marijuana (Baron, 2015; Small & Beckstead, 1973; Small & Marcus, 2003). Traditionally, these strains are ingested for recreational, spiritual, and medicinal purposes due to the psychotomimetic, or mood-altering, effects of THC (Grotenhermen, 2003; Madras, 2015; Small & Beckstead, 1973). Conversely, species containing little to no THC and high levels of the non-psychoactive cannabinoid, cannabidiol (CBD), are often referred to as industrial hemp (Small & Marcus, 2003). These strains are commonly used to produce a variety of practical materials such as paper, textiles, food, and soaps, though hemp is also used for medicinal purposes (Baron, 2015).

Medical Uses of Cannabis

Cannabis has a long-standing history in medicine, dating back to 900 B.C. (Baron, 2015). However, it was not until the 19th century that this plant gained acceptance in the Western world as an effective medical remedy (Baron, 2015; Madras, 2015). During that time, physicians used cannabis for its analgesic properties (e.g., O'Shaughnessy, 1843) and for the treatment of migraine (Clendinning, 1843), cough, gonorrhea, and even "hysterical insanity" (McMeens, 1860, p. 130). Today, researchers have investigated the use of cannabis for a wide variety of medical conditions and symptoms related to neurological disease (e.g., multiple sclerosis [MS], neuropathic pain, Alzheimer's disease, epilepsy, etc.), cancer and chemotherapy, Crohn's disease, posttraumatic stress disorder (PTSD), and glaucoma (Madras, 2015).

Presently, there are an extensive number of research studies evaluating the effectiveness of cannabis for such purposes. Although a full review of such studies is beyond the scope of this dissertation, there are several promising areas of investigation. Thus far, research tends to support the use of cannabis for the reduction of nausea and vomiting associated with chemotherapy, as evidenced by two meta-analytic reviews (e.g., Machado Rocha, Stéfano, De Cássia Haiek, Rosa Oliveira, & Da Silveira, 2008; Tramèr et al., 2001). Cannabis may also be effective for the treatment of spasticity and pain in patients with MS (e.g., Corey-Bloom et al., 2012; Rog, Nurmikko, Friede, & Young, 2005; Zajicek, Hobart, Slade, Barnes, & Mattison, 2012). The use of cannabis for managing diabetic neuropathy (e.g., Wallace, Marcotte, Umlauf, Gouaux, & Atkinson, 2015), HIV/AIDS neuropathy (e.g., Ellis et al., 2009), and chronic pain (e.g., Hill, 2015; Narang et al., 2008; Ware et al., 2010) are additional areas of promise.

Despite evidence supporting the medicinal value of cannabis, several limitations preclude nation-wide acceptance. Primary concerns regarding the use of cannabis as a medical treatment include the plant's varying composition across strains and preparations, unpredictable doses, intoxicating effects, and abuse potential (Madras, 2015). For example, scientists have only recently begun to understand the therapeutic impact of varying THC and CBD ratios and their role amongst the plant's 545 distinct natural compounds (Elsohly & Slade, 2005; ElSohly & Gul, 2014). Unsurprisingly, the intricate composition of cannabis makes it difficult to determine accurate dosing, further complicating the matter. Method of ingestion (e.g., smoking vs. oral administration) may also obscure accurate dosage due to variations in bodily absorption. Ultimately, these factors will affect one's degree of intoxication, experience of unwanted side effects, and the likelihood of future abuse (Madras, 2015).

Despite the plant's complex chemical makeup, cannabis can be cultivated or prepared to achieve ideal THC and CBD ratios (Hillig & Mahlberg, 2004; Potter, 2014). This is particularly important when treating certain medical conditions, which may require precise and consistent concentrations of specific cannabinoids (Potter, 2014). However, despite these pharmaceutical advances, some users prefer smoking the whole plant over ingesting isolated cannabinoids to maximize therapeutic benefit. The belief that maximum benefit is achieved from whole plant preparations is consistent with the "entourage effect" (Ben-Shabat et al., 1998; Madras, 2015). The entourage effect suggests that the therapeutic benefits of cannabis are due, in part, to the interaction between active and inactive compounds (Russo, 2011). As a result, isolating THC and/or CBD may reduce the plant's therapeutic efficacy (Maa & Figi, 2014; Madras, 2015). Nevertheless, the ability to extract, isolate, and control THC and CBD ratios is invaluable for the treatment of certain disorders.

Pharmacology of Cannabis

Pharmacodynamics. In general, cannabis produces alterations in cognition, perception, and behavior through the release of THC, the plant's primary psychoactive component (Gonzalez, 2007).

After cannabis is ingested, THC binds to endogenous cannabinoid receptors 1 (CB_1) and 2 (CB_2), located primarily in brain tissue and peripheral immune tissue, respectively (Devane, Dysarz, Johnson, Melvin, & Howlett, 1988; Galiègue et al., 1995). These receptors play a significant role in the endocannabinoid system, which is responsible for a wide array of physiological processes, such as appetite (Maccarrone et al., 2010), immune function (Croxford & Yamamura, 2005), learning and memory (Marsicano & Lafenêtre, 2009), and sleep/wake cycles (Murillo-Rodríguez et al., 2011). Although a "type-3" cannabinoid receptor may exist, its role in the endocannabinoid system is currently less understood (Moriconi, Cerbara, Maccarrone, & Topai, 2010).

Within the brain, the binding of THC with CB_1 receptors suppresses the release of both inhibitory and excitatory neurotransmitters, including dopamine, serotonin, gamma-aminobutyric acid (GABA), and glutamate (Atakan, 2012; Baron, 2015). These neurotransmitters have important implications for cognition, memory, and motor function in areas dense with CB_1 receptors, such as the cerebellum (which is involved in coordination and cognition), hippocampus (which is involved in learning and memory), and basal ganglia (which is involved in motor control; Glass, Faull, & Dragunow, 1997; Herkenham et al., 1990; Madras, 2015). For example, the suppression of glutamate in the hippocampus may interfere with LTP, the process responsible for learning and memory (Misner & Sullivan, 1999; Stella, Schweitzer, & Piomelli, 1997). Alterations in neurotransmitter activity also mediate the euphoric effects of cannabis (Baron, 2015; Cheer, Wassum, Heien, Phillips, & Whightman, 2004; Fadda et al., 2006). Ultimately, these neural alterations, among others, contribute to users' experience of acute intoxication.

While THC receives considerable attention for its psychoactive effects, CBD is largely recognized for its anticonvulsive, antipsychotic, and anxiolytic properties (Mechoulam, Parker, & Gallily, 2002; Morgan & Curran, 2008; Zuardi et al., 2012). Although CBD's mechanisms of action are still not well understood, CBD demonstrates a low affinity for CB_1 and CB_2 receptors and instead interacts with a variety of non-endocannabinoid systems (Devinsky et al., 2014; Izzo, Borrelli, Capasso, Marzo, & Mechoulam, 2009; Zuardi et al., 2012). These complex interactions, which are beyond the scope of this paper, are thought to limit the psychoactive effects of THC (Bhattacharyya et al., 2010; Koppel et al., 2014). As a result, CBD may be effective for improving users' tolerability to the plant, thereby broadening its therapeutic potential (Devinsky et al., 2014). Unfortunately, THC potency has steadily increased over the last 20 years, such that concentrations of THC are 80 times that of CBD in a typical cannabis plant (12% and < 0.15%, respectively; ElSohly et al., 2016). This is particularly concerning given that high levels of THC may be associated with neurotoxicity in chronic users (Rocchetti et al., 2013).

Pharmacokinetics. As suggested previously, users' experience of acute intoxication will depend on cannabinoid concentrations and rates of bodily absorption, which vary as a function of several factors. These factors include cannabis strain, preparation (e.g., dried plant matter, oil, hashish), and method of ingestion (e.g., pipe, joint, vaporizer, edible; Grotenhermen, 2003; Huestis, 2007). Although there are a variety of approaches to cannabis consumption, smoking remains the most popular method due to the rapid onset of psychotropic effects (Gonzalez, 2007). When cannabis is smoked, blood plasma concentrations generally peak around 10 minutes, with psychotropic effects peaking after 20-30 minutes and resolving after about 4 hours (Hollister et al., 1981; Huestis, Sampson, Holicky, Henningfield, & Cone, 1992). However, inhalation characteristics, such as depth of inhalation and duration of breath hold, may moderate the intensity and duration of such properties (Gonzalez, 2007). Conversely, oral consumption requires 60-120 minutes to reach peak plasma concentration levels and maximum psychotropic effects (Curran, Brignell, Fletcher, Middleton, & Henry, 2002; Hollister et al., 1981). Due to slower rates of bodily absorption with this method of ingestion, resolution of subjective psychotropic effects may take up to 6 hours.

Subjective effects of intoxication. Cannabis users report a wide variety of psychological and physiological effects in response to acute intoxication (Grotenhermen, 2003). Notably, users often describe a positive experience, characterized by feelings of relaxation, euphoria, laughter, and creativity (Green, Kavanagh, & Young, 2003; Grotenhermen, 2003; Zeiger et al., 2012). Unpleasant feelings such as lethargy, anxiety, and paranoia are also reported, though they reputedly occur less frequently (Green et al., 2003; Zeiger et al., 2012; Zuurman, Ippel, Moin, & van Gerven, 2009). Other common experiences include increased heart rate, heightened sensory perception, distorted sense of time, and enhanced appetite (Baron, 2015; Green et al., 2003). However, despite these common experiences, the acute effects of cannabis are variable between users, and even within users depending upon the type of cannabis consumed (Green et al., 2003).

Neuroimaging Findings

Although the acute effects of cannabis resolve in a matter of hours, chronic use may lead to effects that persist beyond the window of acute intoxication. For example, repeated cannabinoid exposure may lead to alterations in brain structure and function, which may increase risk for long-term psychiatric consequences such as schizophrenia (Moore et al., 2007; Large, Sharma, Compton, Slade, & Nielssen, 2011). Fortunately, a variety of neuroimaging technologies are now available to explore the neural alterations associated with acute and chronic cannabis use.

Functional effects of acute intoxication.

Resting state. Neuroimaging techniques, such as positron emission tomography (PET) and functional magnetic resonance imaging (fMRI), allow researchers to investigate the acute effects of cannabis intoxication on brain function (Blumenfeld, 2010). One area of interest concerns alterations in resting state activity, or neural activity that occurs in the absence of overt stimuli (Blumenfeld, 2010; Klumpers et al., 2012). In a review of such studies, Batalla, Crippa, and colleagues (2014) found several consistent findings regarding the acute effects of cannabis on resting state activity. Researchers commonly reported increased global cerebral blood flow (CBF) relative to placebo or baseline measurements (e.g., Mathew et al., 1999; Mathew, Wilson, Coleman, Turkington, & DeGrado, 1997; Volkow et al., 1991). Similarly, increased CBF was observed in specific brain regions, especially in the prefrontal cortex, insula, cerebellum, and anterior cingulate (Mathew et al., 1997; Mathew et al., 1999; Mathew & Wilson, 1993; Mathew, Wilson, Humphreys, Lowe, & Wiethe, 1992; Mathew, Wilson, Turkington, & Coleman, 1998; van Hell et al., 2011). Activation of such regions in the absence of specific stimuli was also associated with users' experience of intoxication, particularly feelings of euphoria (van Hell et al., 2011), depersonalization (Mathew et al., 1999; Mathew & Wilson, 1993), anxiety (Mathew & Wilson, 1993), and distorted sense of time (Mathew et al., 1998).

Activation during cognitive tasks. Researchers are also interested in the acute effects of cannabis on patterns of neural activity during cognitive tasks. Two studies have assessed associative memory functions after the administration of THC (Bhattacharyya et al., 2009; Bossong, Jager, et al., 2012). Participants in these studies demonstrated a reduction in encoding activity, perhaps in response to medial temporal and prefrontal alterations (Bhattacharyya et al., 2009). However, THC was also related to increased activity in the parahippocampal gyrus during subsequent encoding blocks (Bhattacharyya et al., 2009). This finding suggests that, while traditional encoding mechanisms may be compromised during acute cannabis intoxication, the brain may recruit additional areas to compensate for such alterations (Batalla, Crippa, et al., 2014). Although THC intoxication did not influence task performance in the aforementioned studies, a separate study found reduced performance on a working memory task following THC administration. Reduced performance was associated with increased activity in working memory networks, including the dorsolateral prefrontal cortex, inferior temporal and parietal gyri, and the cerebellum (Bossong, Jansma, et al., 2012).

Altered brain activity during acute intoxication is common in occasional users while performing a variety of other cognitive tasks. For example, attentional tasks were associated with increased activity in the ventral forebrain and cerebellum in several studies employing within-subject placebo-controlled designs, whereas decreased activity was observed in posterior visual regions (O'Leary et al., 2002; O'Leary et al., 2007). In addition, motor performance was associated with increased cerebellar and ventral frontal lobe activity after smoking a cannabis cigarette relative to a placebo cigarette (O'Leary et al., 2003). With regard to decision-making, researchers have found attenuated activity in frontal, temporal, and parietal regions as well as areas of the cingulate gyrus, which may play a role in reduced appreciation for rewards (van Hell et al., 2012). Acute THC intoxication may also moderate amygdala and anterior cingulate activation during affective processing tasks (Phan et al., 2008; Rabinak, Sripada, Angstadt, de Wit, & Phan, 2012). Neural changes are also observed in naïve users during sensory processing (Winton-Brown et al., 2011), attentional salience processing (Bhattacharyya et al., 2012), and response inhibition tasks (Borgwardt et al., 2008).

Researchers are also interested in the differential impact of CBD on brain activity during cognitive tasks. Thus far, neuroimaging findings suggest that CBD produces opposite effects on regional brain activity relative to THC. For example, during an attentional salience processing task, THC augmented activity in the right superior, middle, inferior, and orbitofrontal gyri, whereas CBD attenuated activity (Bhattacharyya et al., 2012). Similarly, in areas where THC attenuated activity, CBD augmented activity (Bhattacharyya et al., 2012). Researchers have replicated comparable opposite effects in different brain regions (Winton-Brown et al., 2011). These findings have important implications with regard to the distinct psychological states associated with THC and CBD. Specifically, one study found an association between temporal attenuation and self-reported psychotic symptoms following the acute administration of THC (Winton-Brown, 2011). Another study found significant reductions in subjective anxiety in response to CBD modulation of limbic and paralimbic regions (Crippa et al., 2004). Thus, variations in THC- and CBD-associated psychological states may have distinct neural correlates.

Overall, there appear to be a variety of neural alterations in response to the acute effects of cannabis, with several consistent findings (Batalla, Crippa, et al., 2014). With regard to resting state activity, acute intoxication is consistently associated with global increases in CBF, though regional increases are also observed, particularly in areas that are dense with CB_1 receptors. Similarly, alterations in neural activity are observed during cognitive tasks, with both increases and decreases in brain activity in response to various paradigms. Of note, the alteration and recruitment of different brain regions may reflect a compensatory mechanism for preserving cognitive abilities. In addition to the aforementioned findings, CBD-related alterations in various brain regions are opposite to those of THC, supporting the notion that CBD acts as a moderator of THC's psychoactive effects. Furthermore, the opposite activities of THC and CBD may explain their differential psychological profiles.

Chronic effects of cannabis.

Structural effects of chronic cannabis use. In addition to the functional changes associated with acute cannabis intoxication, researchers have sought to clarify the structural consequences of long-term cannabis consumption. Unfortunately, the definition of chronic cannabis use varies widely across samples. For example, some studies require regular use in the last 6 months (e.g., ≥ 4 times per week; Schacht, Hutchison, & Filbey, 2012), whereas other researchers have examined samples with 21 years of regular use (e.g., Lorenzetti et al., 2015). To obtain information regarding brain structure, researchers often utilize structural magnetic resonance imaging (MRI). This imaging method is preferred over computerized tomography (CT) due to its ability to identify slight changes in neuroanatomy through the generation of high-contrast, detailed images (Blumenfeld, 2010). Research has repeatedly demonstrated similar levels of intracranial volume (or the available space for one's brain to fill) between adult cannabis users and non-users, suggesting that chronic cannabis use does not have a significant effect on intracranial brain volume (Batalla, Soriano-Mas et al., 2014; Block et al., 2000; Cousijn et al., 2012; Schacht, Hutchison, & Filbey, 2012; Tzilos et al., 2005; Solowij, Yücel, Respondek, Whittle, & Lindsay, 2011). Similarly, research has found comparable whole brain volumes between users and non-users (Block et al., 2000; Zalesky et al., 2012). Studies on cerebrospinal fluid (CSF) volumes are less consistent, with some studies identifying similar volumes between groups (Tzilos et al., 2005) and others identifying lower volumes in users (Block et al., 2000).

With regard to regional comparisons, chronic cannabis users consistently demonstrate smaller hippocampal volumes relative to healthy controls (Demirakca et al., 2011; Lorenzetti et al., 2015; Matochik, Eldreth, Cadet, & Bolla, 2005; Schacht et al., 2012; Yücel et al., 2008). Notably, these changes may be related to dosage and lifetime exposure, such that greater severity and duration of use, as well as greater THC potency, are associated with reductions in hippocampal volume (Demirakca et al., 2011; Matochik et al., 2005). However, despite those findings, several studies report similar hippocampal volumes in users and non-users (Block et al., 2000; Smith et al., 2015; Tzilos et al., 2005; Weiland et al., 2015). Volumetric reductions are also relatively consistently found in the amygdala (Lorenzetti et al., 2015; Schacht et al., 2012) and areas of the prefrontal cortex (Battistella et al., 2014; Filbey et al., 2014). Alternatively, evidence for a relationship between cannabis use and volumetric changes is variable in other regions. For example, in the cerebellum of chronic users, some researchers have found decreased white matter (Solowij et al., 2011), some found increased grey matter (Cousijn et al., 2012), and some found no volumetric differences (Weiland et al., 2015).

Diffusion tensor imaging (DTI) is another method to identify structural changes, though it instead provides information regarding white matter integrity and tract coherence (Arnone et al., 2008; Blumenfeld, 2010). These characteristics are quantified through measures of mean diffusivity (a measure of structural integrity) and fractional anisotropy (FA; a measure of tract coherence; Arnone et al., 2008). Mean diffusivity will increase and FA will decrease when boundaries to water diffusion are reduced (Arnone et al., 2008). In using DTI to compare chronic cannabis users and non-users, Arnone et al. (2008) found greater mean diffusivity in users' corpus callosum, particularly between the prefrontal lobes, though FA values were nonsignificant. Alternatively, Gruber, Silveri, Dahlgren, and Yurgelun-Todd (2011) found lower FA in the left frontal lobe of chronic users compared to non-users, which was positively correlated with age of onset (Gruber et al., 2011). These white matter alterations may explain several functional abnormalities observed in chronic cannabis users, such as impaired executive control and increased impulsivity (Arnone et al., 2008; Gruber et al., 2011).

Functional effects of chronic cannabis use.

Resting state. Although structural changes in chronic cannabis users are minimal, subtle alterations may be further characterized using functional imaging methods. For example, several studies have identified differences in resting state activity between chronic cannabis users and non-users (Batalla et al., 2013). With regard to regional CBF, researchers have reported increases in the anterior cingulate (Block et al., 2000) and decreases in cerebellar and prefrontal regions (Block et al., 2000; Lundqvist, Jönsson, & Warkentin, 2001). Chronic users have also displayed lower glucose metabolism in several areas, including the putamen (within the basal ganglia) and the right orbitofrontal cortex (Sevy et al., 2008). However, users and non-users tend to demonstrate similar striatal dopamine D_2/D_3 receptor availability (Albrecht et al., 2013; Sevy et al., 2008; Stokes et al., 2012). Furthermore, although cannabis users have displayed region-specific reductions in CB_1 receptors, density appears to restore following one month of abstinence (Hirvonen et al., 2012). Similarly, altered basal ganglia connections are no longer observed in the context of sustained abstinence (Blanco-Hinojo et al., 2016).

Activation during cognitive tasks. Researchers have also examined the effects of chronic cannabis use on patterns of neural activity during a variety of cognitive tasks. In the domain of attention and working memory, cannabis users consistently displayed differential patterns of brain activity in areas such as the prefrontal cortex, parietal lobe, and cerebellum (Chang, Yakupov, Cloak, & Ernst, 2006; Jager, Kahn, Van Den Bring, Van Ree, & Ramsey, 2006; Kanayama, Rogowska, Pope, Gruber, & Yurgelun-Todd, 2004). Researchers have also observed increased connectivity between regions, namely the frontal cortex and occipitoparietal cortex (Harding et al., 2012). However, despite these differences, users and non-users demonstrated similar performance on verbal and visual tasks of attention and working memory (Chang et al., 2006; Harding et al., 2012; Jager et al., 2006; Smith, Longo, Fried, Hogan, & Cameron, 2010). Given the comparable performance between users and non-users, alterations in neural activity may provide further evidence for a compensatory mechanism in cannabis users (Harding et al., 2012; Kanayama et al., 2004).

Several researchers have also examined functional changes in chronic cannabis users while engaging in tests of learning and memory. One study found that poorer verbal memory was associated with attenuated activity in the prefrontal cortex, increased activity in the posterior cerebellum, and the absence of lateralized hippocampal activation (Block et al., 2002). Similarly, cannabis users demonstrated reduced activation of the dorsolateral prefrontal cortex and bilateral parahippocampal gyri during an associative memory task; though users and non-users did not differ in their performance (Jager et al., 2007). Consistent with such findings, a separate study identified hypoactivity in frontocortical regions during an associative learning paradigm (Nestor, Roberts, Garavan, & Hester, 2008). However, the researchers observed greater, rather than reduced, activity in the right parahippocampal gyrus during learning (Nestor et al., 2008). Once more, these researchers concluded either a possible compensatory mechanism or changes in cerebral perfusion as a consequence of chronic cannabis use (Jager et al., 2007; Nestor et al., 2008).

Neural alterations were also evident across a variety of other tasks, despite comparable performance. For example, in the anterior cingulate cortex of chronic users, researchers have observed increased (Gruber, Dahlgren, Sagar, Gonenc, & Killgore, 2012) or decreased (Hester, Nestor, & Garavan, 2009) activity during tasks of inhibitory control. Similarly, chronic cannabis users have displayed increased (Vaidya et al., 2012) or decreased (Wesley, Hanlon, & Porrino, 2011) activity in the ventromedial prefrontal cortex (vmPFC) and cerebellum during decision-making tasks. In the latter group, users generally performed more poorly than non-users, though group performance was similar during the phase in which decreased activity was observed (Wesley et al., 2011). Cannabis users have also demonstrated increased activation of the superior frontal gyri and decreased activation of the superior lingual gyri, which were associated with slower and less efficient psychomotor abilities (King et al., 2011). Finally, users have displayed attenuated anterior cingulate and amygdalar activity in response to affective processing (Gruber, Rogowska, & Yurgelun-Todd, 2009).

Overall, there are numerous research studies examining the effects of chronic cannabis use on brain structure and function. There are several regions in which structural alterations are consistently observed, including the hippocampus, amygdala, cerebellum, and frontal cortex (Batalla, et al., 2013). Chronic users also display altered functional activity, particularly in prefrontal cortical, cerebellar, and striatal regions. However, it is noteworthy that cognitive performance between users and non-users is comparable in neuroimaging studies, despite neural alterations that would be expected to result in poorer performance in areas such as memory and executive functioning. Furthermore, several studies suggest the recovery and restoration of certain neural qualities following sustained abstinence (Blanco-Hinojo et al., 2016; Chang et al., 2006; Hirvonen et al., 2012).

Although evidence suggests that chronic cannabis use is associated with structural and functional alterations in the brain, the studies reviewed herein do not address the neural consequences of adolescent cannabis use. A review of such consequences is beyond the scope of this paper; however, adolescents may be more susceptible to the adverse effects of cannabis due to the neurodevelopmental changes that occur during that period (Lisdahl, Gilbart, Wright, & Shollenbarger, 2013; Volkow et al., 2016). Given adolescent vulnerability to neural alterations, age of cannabis use onset also has important implications regarding the severity of neural changes and neuropsychological impairment observed in adults (Gruber et al., 2012; Lopez-Larson et al., 2011; Sagar et al., 2015; Zalesky et al., 2012).

Neuropsychological Assessment

Presumably, structural and functional changes in cannabis users should correlate with cognitive performance on neuropsychological testing. For example, researchers have found a positive correlation between larger hippocampal volumes and superior verbal learning and memory in non-users, but not in users (Ashtari et al., 2011). However, associations between cognitive performance and neural alterations are not apparent in the overwhelming majority of studies reviewed previously. As a result, researchers turn to neuropsychological assessment to further clarify the acute and chronic effects of cannabis on cognitive functioning. Given the proliferation of such research, the majority of this review will focus on studies published in the last 10 years.

Acute effects of cannabis on neuropsychological performance. There is increasing evidence to support the widely-held belief that users experience impaired attention under the acute intoxication of cannabis (Broyd et al., 2016). In fact, researchers have found impairments in selective (Anderson, Rizzo, Block, Pearlson, & O'Leary, 2010), divided (Anderson et al., 2010; Bedi, Cooper, & Haney, 2013; Theunissen et al., 2014), and sustained attention (D'Souza, Ranganathan, et al., 2008; Hunault et al., 2009) under acute intoxication. Furthermore, impairments may be dose-dependent, such that greater impairments are observed with larger doses of THC (Hunault et al., 2009). Despite these findings, some researchers have failed to find an effect of acute intoxication on attention, specifically in chronic users. This may be the result of increased tolerance to the drug and compensatory strategies (Ramaekers, Kauert, Theunissen, Toennes, Moeller, 2009; Schwope, Bosker, Ramaekers, Gorelick, & Huestis, 2012).

Researchers also commonly document memory impairments in cannabis-intoxicated individuals, particularly in the domain of verbal learning and memory (Broyd et al., 2016). For example, researchers have found poorer immediate and delayed verbal recall in acutely intoxicated individuals, and even poorer recognition memory (D'Souza, Braley, et al., 2008; Ranganathan et al., 2012; Theunissen et al., 2014; Wesnes et al., 2010). However, there is evidence that CBD may mitigate or eliminate the effects of THC on verbal memory (Englund et al., 2013; Morgan, Schafer, Freeman, & Curran, 2010). Acutely intoxicated individuals have also demonstrated impairments on associative memory (Ballard, Gallo, & de Wit, 2012), prospective memory (Theunissen et al., 2014) and procedural learning tasks (Dumont et al., 2011). Alternatively, visual and spatial recognition memory appear to remain intact under acute intoxication (Anderson et al., 2010; D'Souza, Braley, et al., 2008; Ranganathan et al., 2012), though higher doses of THC may result in slower visual recognition reaction times (Wesnes et al., 2010).

The majority of research also provides evidence for psychomotor impairments during acute cannabis intoxication, specifically in critical tracking, reaction time, and motor control (D'Souza, Braley et al., 2008; Hunault et al., 2009; Theunissen et al., 2014; Weinstein et al., 2008; Wesnes et al., 2010). However, psychomotor abilities appear to be less impaired in acutely intoxicated *chronic* users (Ramaekers et al., 2009; Schwope et al., 2012). Although cannabis-intoxicated individuals generally exhibit diminished psychomotor abilities, the effects of acute intoxication are variable on executive function tasks, despite their underlying motor components (Crane, Schuster, Fusar-Poli, & Gonzalez, 2012). For example, some studies report impaired motor inhibition (Ramaekers et al., 2009; Theunissen et al., 2012; Theunissen et al., 2014), whereas others do not (Ramaekers et al., 2011). Findings are also variable for other executive functioning tasks, such as response inhibition (Liem-Moolenaar et al., 2010; Ranganathan et al., 2012), mental flexibility (Anderson et al., 2010; Weinstein et al., 2008), and decision-making (Metrik et al., 2012; Vadhan et al., 2007). Similarly, the acute effects of cannabis on the domain of working memory are mixed, with some studies reporting impaired performance (Englund et al., 2013; Morrison et al., 2009; Theunissen et al., 2014; Wesnes et al., 2010) and others failing to find an effect (Bedi, et al., 2013; Kollins et al., 2015; Ranganathan et al., 2012).

Overall, there are several consistent findings with regard to the acute effects of cannabis on neuropsychological functioning. Notably, acute intoxication generally produces impairments in attention, verbal learning and memory, and psychomotor functioning. Researchers have also observed impairments in working memory and executive functioning; however, the evidence base is somewhat variable. These variations may be due to multiple factors, including THC dose, route of administration (which will influence the onset and duration of psychoactive effects), lifetime exposure to cannabis, and the wide range of neuropsychological measures employed (Broyd et al., 2016).

Residual effects of cannabis on neuropsychological performance. Given the neuropsychological impairments associated with acute cannabis intoxication, researchers are increasingly interested in evaluating the long-term, or residual, neuropsychological effects of chronic cannabis use. However, prior to reviewing such effects, it is important to further clarify the term *residual*. Notably, residual effects are those that persist beyond the window of acute intoxication and period of clinical symptoms, which may take two to four weeks to fully diminish (Budney, 2004; Ganzer et al., 2016; Pope, Gruber, & Yurgelun-Todd, 1995). Regrettably, studies investigating the residual effects of chronic cannabis employ variable and insufficient periods of abstinence, which has led to significant ambiguity regarding the true residual effects of cannabis (Ganzer et al., 2016). As a result, the following section will focus on studies requiring at least 14 days of abstinence to exclude findings that may be due to withdrawal symptoms or drug residues (Ganzer et al., 2016). Given that this restriction limits the number of adult studies, adolescent findings will also be reviewed.

Similar to the acute effects of cannabis on cognitive functioning, the domain of attention is consistently impaired after a sustained period of abstinence in chronic users. For example, adults have displayed impairments in visual (Chang et al., 2006) and divided attention (Bosker et al., 2013), though similar attentional performance as observed in non-users has also been reported (Lyons et al., 2004). Impairments in attention are also frequently observed in adolescent populations following sustained abstinence (Hanson et al., 2010; Jacobsen, Mencl, Westerveld, & Pugh, 2004; Medina et al., 2007).

Adult and adolescent chronic cannabis users may also demonstrate residual impairments in learning and memory, though this is primarily true for verbally-based tasks. In particular, adult chronic users have demonstrated reduced verbal memory span and delayed recall, as well as increased rates of forgetting (Pujol et al., 2014). Similarly, adolescent chronic users displayed poorer verbal learning and recall after a period of abstinence (Hanson et al., 2010; Jacobsen, Pugh, Constable, Westerveld, & Mencl, 2007; Jacobus et al., 2012; Medina et al., 2007). Alternatively, abstinent adults and adolescents generally do not display impairments on visual memory tasks (Chang et al., 2006; Hooper, Woolley, & De Bellis, 2014; Lyons et al., 2004) and abstinent adolescents also do not show impairment on spatial working memory tasks (Padula, Schweinsburg, & Tapert, 2007; Schweinsburg et al., 2010). Consistent with such findings, adolescent cannabis users have demonstrated intact, and even superior, visuospatial performance following sustained abstinence (Medina et al., 2007; Winward, Hanson, Tapert, & Brown, 2014).

In line with research regarding the effects of acute cannabis intoxication on psychomotor functioning, abstinent adult and adolescent chronic cannabis users have generally displayed impaired psychomotor abilities (Bosker et al., 2013; Chang et al., 2006; Medina et al., 2007; Pillay et al., 2008; Winward et al., 2014). In contrast, findings regarding executive function performance are less clear. For example, although adult cannabis users tend to demonstrate poorer decision-making after sustained abstinence (Bolla, Eldreth, & Matochik, 2005; Verdejo-Garcia et al., 2007), researchers have reported similar levels of response inhibition and mental flexibility compared to controls (Eldreth, Matochik, Cadet, & Bolla, 2004; Lyons et al., 2004). Similarly, although adolescents have displayed impairments in planning (Medina et al., 2007) and mental flexibility (Tapert et al., 2007; Winward et al., 2014), several other researchers have reported intact executive functions (Hooper et al., 2014; Medina, Nagel, & Tapert, 2010).

To help clarify the residual effects of chronic cannabis use on cognitive functioning, several researchers have conducted meta-analytic reviews. One meta-analysis of 33 studies found a small, but significant, negative effect of cannabis on global neurocognitive performance ($g = -0.29$; Schreiner & Dunn, 2012). Similarly, a small negative effect was observed across most domains assessed. However, when the authors included only those studies that required at least 25 days of abstinence ($n = 13$), the global effect was no longer significant ($g = -0.12$). Furthermore, they no longer observed an effect in any of the cognitive domains assessed. A more recent meta-analytic review assessed the residual cognitive effects of cannabis following 14 days of sustained abstinence to widen the database of potential studies (Ganzer et al., 2016). Out of 31 studies, the authors detected a significant effect across all domains except visuospatial functioning using Fisher's *Z*-transformation, including overall global cognition (r_{mean} = .31), attention (r_{mean} = .27), motor function (r_{mean} = .48), executive functions (r_{mean} = .29), and learning and memory (r_{mean} = .23). However, the authors note that the results should be interpreted with caution, as 14 days may not be adequate to achieve maximal washout. Furthermore, a significant number of studies utilized adolescent populations, an age group that is generally more vulnerable to the residual effects of cannabis.

Overall, both acute and chronic cannabis use appear to have a negative effect on neurocognitive performance, though the degree and severity of such effects are variable across domains and may resolve with sufficient abstinence (Schreiner & Dunn, 2012). Impairments in the domains of attention, learning and memory, and psychomotor functioning appear to be relatively consistent. However, findings are variable across other domains, including working memory and executive functioning. As mentioned previously, a variety of factors may contribute to variable findings. Of note are the diverse characteristics across studies (i.e., population demographics, definition of chronic cannabis use, length of abstinence, cognitive tasks performed), which make comparisons between studies exceptionally difficult (Batalla et al., 2013). Furthermore, some researchers fail to control for confounding factors, such as neurological, psychiatric, and other drug use history, particularly alcohol use (Gonzalez, Cary, & Grant, 2002).

Another methodological limitation worth noting is the lack of performance validity testing (i.e., effort put forth to perform one's best during testing) implemented in the majority of studies discussed. This is concerning given the impact of effort on neuropsychological test scores (Green, 2007; Meyers, Volbrecht, Axelrod, & Reinsch-Boothby, 2011) and the recommendation that performance validity tests (PVTs) be included in all cognitive batteries (Bush et al., 2005; Heilbronner, Sweet, Morgan, Larrabee, & Millis, 2009). However, validity measures are almost never included when evaluating the cognitive effects of cannabis, despite the "amotivational syndrome" thought to occur in regular cannabis users (McGlothlin & West, 1968). As a result, poor effort or motivation may explain some of the deficits observed in the literature thus far. For example, researchers have found that differences between users and non-users on a test of verbal learning were no longer significant following a statement designed to enhance motivation to perform well on testing (Macher & Earleywine, 2012). Further, another study suggested that effort mediates the relationship between frequency of cannabis use and learning and memory performance (Hirst, Young, Sodos, Wickham, & Earleywine, 2016). These findings support the necessity of validity testing in chronic cannabis users, especially when drawing conclusions regarding neuropsychological impairment.

Similarly, the overwhelming majority of studies assessing the cognitive effects of cannabis use do not utilize examiners who are blind to participant user status. However, similar to the administration of eyewitness lineup identification tasks, it is essential that examiners are blind to user status to prevent experimenter expectancy effects (Rosenthal & Rosnow, 2007). This is particularly important given that perceptions regarding user status are associated with perceived impairments in memory performance (Hirst et al., 2017). Thus, if researchers do not implement blind examiner research paradigms, expectancy effects could influence the performance of cannabis users, contributing to some of the variance observed in neuropsychological test scores.

Current Study

The formation and retrieval of memories is a delicate process that can be easily disrupted, resulting in erroneous recollections. Not only are memories naturally susceptible to error and decay, there are a significant number of factors in the context of eyewitness testimony that may negatively influence one's memory for an event and lineup identification performance. Namely, a variety of system and estimator variables are known to reduce the accuracy of memory, even for an eyewitness with the best intentions. Clarifying the effect of such variables on eyewitness memory will ultimately improve judges' ability to make informed decisions regarding the admissibility of eyewitness evidence or may encourage the inclusion of additional safeguards to protect defendants against erroneous testimony. Further, knowledge of eyewitness factors will facilitate a cautionary approach to rendering a verdict based on eyewitness accounts, reducing the likelihood of wrongful conviction.

Of the many factors that influence eyewitness memory, intoxication is of growing concern due to the frequency in which law enforcement officers come into contact with intoxicated witnesses. Given the negative effect of cannabis on cognitive performance and the rising prevalence of cannabis use on a national and global level, it is essential to evaluate the effects of cannabis on eyewitness accuracy. Presently, there are only two studies evaluating such concerns with regard to the acute effects of cannabis (Vredeveldt et al., 2018; Yuille et al., 1998). The present study will advance the literature in several ways. First, this study will evaluate the effects of chronic cannabis use on eyewitness accuracy following at least 24 hours of abstinence. The author chose to evaluate chronic cannabis users with 24 hours of abstinence (rather than those under the acute influence of cannabis or those with a significant length of abstinence) to investigate ecologically valid eyewitness conditions that have yet to be explored. It is likely that police will encounter not just currently intoxicated witnesses, but frequent, chronic users who may not be intoxicated at the time their eyewitness account is gathered. For example, given that the acute effects of cannabis tend to resolve in four hours (Hollister et al., 1981), it is possible for chronic cannabis users to witness a crime and be interviewed after the period of acute intoxication. It is much less likely that chronic cannabis users will have undergone a significant length of abstinence prior to being interviewed. The following hypotheses will address concerns presented in the literature:

H1: Exploratory analysis to evaluate whether users' and non-users' performance differs significantly on verbal and visual recognition tasks. A direction is not hypothesized given inconsistencies in the literature evaluating the cognitive effects of chronic cannabis use.

H2: Users will provide significantly fewer details of the crime compared to non-users, though the accuracy of details will not differ.

H3: Exploratory analysis to evaluate whether user status and lineup condition (target present vs absent) significantly predict lineup identification accuracy.

H4: Neuropsychological performance will mediate the relationship between user status and eyewitness performance.

CHAPTER II

METHOD

Participants

Twenty-one chronic cannabis users and 19 non-users were recruited from the community. Sample size was determined through an *a priori* G* power calculation for MANOVA global effects, which suggested that approximately 42 participants would be needed when comparing two groups to achieve a power level of .80, with two outcome variables (estimated according to the number of dependent variables in proposed analyses), an alpha (α) of .05, and a medium effect size (ES) of $f^2 = 0.25$. This ES was estimated according to Ganzer and colleagues' (2016) meta-analysis, which yielded a pooled ES of $r_{\text{mean}} = .38$ and an ES of $r_{\text{mean}} = .23$ for the domain of learning and memory.

Inclusion and exclusion criteria. To be minimally eligible for participation, individuals must have (1) been between 18 and 50 years old (to exclude neuro-developmentally inappropriate individuals and individuals experiencing age-related cognitive decline [Aartsen, Smits, van Tilburg, Knipscheer, & Deeg, 2002; Hedden & Gabrieli, 2004; Lisdahl et al., 2013; Rönnlund, Nyberg, Bäckman, & Nilsson 2005]); (2) endorsed English as their first language (or endorsed being fluent and educated in English from the age of 6 to ensure adequate knowledge of the English language to obtain valid neuropsychological test results); and (3) provided voluntary consent for participation.

Individuals were included as a chronic cannabis user if they (1) endorsed current cannabis use; (2) reported using cannabis at least two days a week for the last year; and (3) if they were amenable to abstaining from substances (e.g., cannabis and alcohol) for at least 24 hours prior to their scheduled testing session. Unfortunately, there is no official consensus as to what constitutes "chronic" cannabis use. Examples of this criterion include once weekly for at least one year (Lyons et al., 2004), at least 5,000 lifetime uses (Pillay et al., 2008), or daily use for at least two years (Kelleher, Stough, & Sergejew, 2004). Use of two days per week for the last year was chosen to establish an appropriate group of participants with a "history of 'primarily' marijuana use," consistent with experts' recommendations (Gonzalez et al., 2002, p. 50S). In addition, two days per week is greater than what other researchers have utilized when examining the cognitive effects of chronic cannabis use (e.g., Lyons et al., 2004; Skosnik et al., 2008; Skosnik, Spatz-Glenn, & Park, 2001).

Individuals were included as a non-user control if (1) they had *never* used cannabis OR (2) if they had a history of limited cannabis use (defined as having used no more than 30 times in their lifetime). Non-users with a history of cannabis use (3) must not have used cannabis in the last month. Although some researchers have recommended a control group consisting of individuals having used cannabis at least once, as individuals who have never used cannabis may differ from users in ways that might influence cognitive performance (Pope, Gruber, Hudson, Huestis, & Yurgelun-Todd, 2001; Pope et al., 2003), it is relatively commonplace for cannabis-use research to include drug-naïve controls (e.g., Block et al., 2002; Kelleher et al., 2004; Solowij et al., 2002; Yücel et al., 2008). Moreover, experts in cannabis-use research have defined an appropriate control group as one that includes drug-naïve individuals (Gonzalez et al., 2002; Grant et al., 2003). If non-user controls are to have a history of cannabis use, experts recommend that they have limited experience with cannabis (Gonzalez et al., 2002); in research, this limited experience has ranged from 0 to 50 lifetime uses (Messinis, Kyprianidou, Malefaki, & Papathanasopoulos, 2006; Pope et al., 2003; Solowij et al., 2002; Yücel et al., 2008). Thus, limited experience is reasonably defined as a maximum of 30 lifetime uses, as such use remains distinguishable as experimental/recreational use as opposed to chronic use. In addition, non-users must not have used cannabis in the last month, which should allow for adequate elimination of any cannabis residues from the body prior to study participation (Grotenhermen, 2003; Schreiner & Dunn, 2012).

Exclusionary criteria for all participants included (1) current use of other drugs (defined as other drug use in the last 30 days); (2) other drug use history (e.g., hallucinogens, stimulants, or opiates) exceeding 50 uses (per class of drug); (3) current problematic alcohol use (defined as consumption of two or more drinks on at least four days per week, for the last month or longer); (4) self-report of a current mental health disorder other than simple phobia or social phobia; (5) self-report of a head injury with loss of consciousness and requiring medical intervention in the last six months; (6) current use of psychoactive medication; and (7) self-report of any psychiatric, medical (e.g., cancer and chemotherapy), or neurological condition (e.g., epilepsy, MS) that might interfere with cognitive function. These exclusionary criteria were derived from Gonzalez et al. (2002), who noted the importance of controlling for such confounds due to their effect on neuropsychological performance. Ultimately, failure to control for such factors would obscure our ability to draw conclusions regarding the cognitive effects of cannabis.

Sampling procedure. The author evaluated inclusion and exclusion criteria using an initial online screener (full description provided in the Materials section below), which was active from July 2017 until March 2019. A total of 1196 respondents initiated the screener and consented to proceed; however, only 63.1% (n = 755) provided enough information for qualification and/or scheduling purposes. Of those individuals, 24 indicated that English was not their first language and they were not educated or fluent in English since at least age 6 and were therefore eliminated from further consideration. Of the remaining 731 individuals, 93.7% (n = 685) had tried cannabis at least once. Among those who had tried cannabis, 71.1% (n = 487) had used in the last 30 days (otherwise classified as current cannabis users), whereas 28.9% (n = 198) had not used in the last 30 days (otherwise classified as non-users). The percentage of current cannabis users qualifying for participation was 29.4% (n = 143), whereas 84.3% (n = 167) of non-users and 80.4% (n = 37) of cannabis-naïve respondents qualified for participation as a non-user. Among qualifying respondents (n = 347), 15.3% (n = 53) were successfully scheduled for participation, and 77.4% (n = 41) of those actually completed the study.

Basic demographics. Participants were classified as either users or non-users according to their responses to the initial online screener. Out of 41 participants, 22 (53.7%) were classified as chronic cannabis users and 19 (46.3%) were classified as non-users. One user was excluded from further analyses because English was not their first language and they were not fluent and educated in English since at least age 6. Among users, 52.4% were male (n = 11) and 47.6% were female (n = 10); of note, one person identified as transgender female and was recoded as female given the small frequency of individuals in that group. Users' mean age was 27.24 (SD = 7.25), mean years of education was 14.52 (SD = 1.66), and mean premorbid IQ was 106.38 (SD = 12.34). Among users, 42.9% identified their race as White, 23.8% identified as Hispanic/Latino, 14.3% identified as Black or African American, 14.3%

identified as Asian, and 4.8% identified with two or more races. With regard to income, 42.8% of users reported earning between less than $10k and $30k, 33.3% reported earning between $30k and $60k, 4.8% reported earning between $60k and $90k, 14.3% reported earning between $90k and $150k or more, and 4.8% chose not to disclose their income (see Table 6 for full demographic details).

Among non-users, 36.8% were male (*n* = 7) and 63.2% were female (*n* = 12). Non-users' mean age was 31.47 (*SD* = 7.14), mean years of education was 16.00 (*SD* = 1.76), and mean premorbid IQ was 107.53 (*SD* = 11.82). Among non-users, 26.3% identified their race as White, 10.5% identified as Hispanic/Latino, 5.3% identified as Black or African American, 31.6%, identified as Asian, 5.3% identified as Native Hawaiian or Pacific Islander, and 21.1% identified with two or more races. With regard to income, 21.1% of non-users reported earning between less than $10k and $30k, 31.6% reported earning between $30k and $60k, 31.6% reported earning between $80k and $150k or more, and 15.8% chose not to disclose their income (see Table 6 for full demographic details).

Cannabis-use characteristics. Chronic cannabis users' (*n* = 21) mean age of cannabis-use onset was 15.71 years old (*SD* = 3.12). Users consumed cannabis an average of 5.90 days per week (*SD* = 1.30) at the time they completed the survey. Users reported consuming at such rates for 45.71 months (*SD* = 33.97). Two users reported that they had always consumed cannabis at such rates. The percentage of users with lifetime uses ranging from 90 to 1,000 and from 1,000 to 10,000+ was 47.7% and 52.4% respectively. Cannabis users' last cannabis use was an average of 3.05 days prior to the appointment (*SD* = 4.38). For users' full current and prior cannabis-use patterns and characteristics, please see Tables 1 and 2, respectively.

Among non-users (*n* = 19), 36.8% had never used cannabis. Of those who had tried cannabis, mean age of cannabis-use onset was 22.50 years old (*SD* = 3.73). Non-users' average lifetime uses ranged from 1 to 10. The percentage of non-users who last used 31 days to 6 months ago was 15.8%, whereas 15.8% last used 6 months to 1 year ago, 10.5% last used 1 to 3 years ago, and 5.3% last used 5 or more years ago. Non-users' last cannabis use was an average of 767.51 days prior to the appointment (*SD*

= 903.85). For non-users' full cannabis-use patterns and characteristics, please see Tables 1 and 2, respectively.

Table 1

Cannabis-Use Patterns Among Users and Non-Users

	User Status					
	Users (n = 21)				Non-Users (n = 19)	
	Current MJ Patterns		Prior MJ Patterns		Prior MJ Patterns	
MJ Patterns	*M* (*SD*)	Range	*M* (*SD*)	Range	*M* (*SD*)	Range
Frequency of use (days/week)	5.90 (1.30)	3-7	3.84 (2.43)	1-7	0.50 (0.00)	<1
Duration of use (months)	45.71 (33.97)	6-120	44.13 (61.02)	<1-240		
Type of MJ Consumed[a]						
Dried plant matter	1.30 (1.32)	0-5	1.05 (0.88)	0-3	0.08 (0.29)	0-1
Edibles	0.10 (0.30)	0-1	4.32 (18.33)	0-80	4.33 (14.39)	0-50
Hash	0.05 (0.22)	0-1	0.05 (0.23)	0-1	0.83 (2.89)	0-10
Concentrates	0.14 (0.31)	0-1	0.11 (0.31)	0-1	–	
Tinctures	–		–		–	
Transdermal patch	–		–		–	
Dronabinol	–		–		–	
Nabilone	–		–		–	

Note. MJ = marijuana.
Dashes represent values that were not reported by any participant.
[a]Measured in grams of cannabis.

Table 2

Cannabis-Use Characteristics Among Users and Non-Users

	User Status	
	Users (n = 21)	Non-Users (n = 19)
MJ Characteristics	%	%
Have you ever used MJ?		
Yes	100	63.2
No	–	36.8
When was the last time you used MJ?[a]		
31d to 6m ago		25.0
6m to 1yr ago		25.0
1 to 3yrs ago		16.7
3 to 5yrs ago		8.3
5+ yrs ago		25.0

Table 2 (continued)

Cannabis-Use Characteristics Among Users and Non-Users

	User Status	
	Users (n = 21)	Non-Users (n = 19)
MJ Characteristics	%	%
Do you consider yourself a “regular” MJ user (e.g., using more days than not)?		
Definitely yes	66.7	
Probably yes	28.6	
Might or might not	4.8	
Do you use MJ for medical or recreational purposes?[a]		
Medicinal	14.3	–
Recreational	38.1	100.0
Both	47.6	–
What medical ailments are you treating with MJ?		
Mental health concern	33.3	
Sleep	38.1	
Medical concern (e.g., blood pressure, injury)	28.6	
What is your primary method for MJ consumption?[a]		
Smoking	76.2	50.0
Vaporizing	19.0	–
Oral Ingestion	–	50.0
Sublingual	4.8	–
Does your MJ contain greater levels of THC or CBD?[a]		
THC > CBD	90.5	8.3
CBD > THC	–	–
Equal amounts THC and CBD	9.5	16.7
Unsure	–	75.0

Note. MJ = marijuana.
Dashes represent values that were not reported by any participant.
[a]For non-users, percentages were derived from those who endorsed a history of cannabis use (n = 12).

Other substance-use, psychiatric, and medical characteristics. For full characteristics regarding users’ and non-users’ alcohol use, licit and illicit substance use, and psychiatric history, please see Tables 3 – 5.

Table 3

Alcohol-Use Characteristics Among Users and Non-Users

ETOH Characteristics	Users (*n* = 21) *M* (*SD*)	Users (*n* = 21) Range	Non-Users (*n* = 19) *M* (*SD*)	Non-Users (*n* = 19) Range
Age of first use (years)	16.25 (3.34)	12-26	17.37 (2.97)	12-25
Have you ever consumed ETOH?				
Yes[a]	95.2		100.0	
No[a]	4.8		–	
Do you currently drink ETOH?				
Yes[a]	66.7		78.9	
No[a]	28.6		21.1	

	Users: Current ETOH Use? Yes *M* (*SD*)	Yes Range	No *M* (*SD*)	No Range	Non-Users: Current ETOH Use? Yes *M* (*SD*)	Yes Range	No *M* (*SD*)	No Range
Frequency (days/week)	1.57 (0.98)	<1-3			1.93 (1.85)	<1-7		
Duration of use (months)	52.32 (70.00)	<1-240			51.90 (78.87)	<1–240		
No. drinks/sitting	2.39 (1.53)	<1-6			1.50 (0.87)	<1-4		
Prior frequency (days/week)	1.50 (1.00)	1-3	1.58 (2.65)	<1-7	1.50 (0.84)	1-3	0.88 (0.75)	<1-2
Prior duration of use (months)	47.50 (52.91)	8-168	94.75 (142.50)	<1-360	33.40 (39.57)	<1-120	81.38 (146.16)	<1-300
Prior no. drinks/sitting	1.50 (1.89)	<1-6	3.17 (4.43)	<1-12	1.40 (0.81)	<1-3	0.63 (0.25)	<1-1

Table 3 (continued)

Alcohol-Use Characteristics Among Users and Non-Users

	Current ETOH Use?			
	Users		Non-Users	
	Yes	No	Yes	No
ETOH Characteristics	%	%	%	%
When did you stop drinking ETOH?[b]				
31d – 6m ago		33.3		25.0
6m – 1yr ago		16.7		–
1 – 3yrs ago		16.7		50.0
3 – 5yrs ago		16.7		–
5+ yrs ago		16.7		25.0

Note. ETOH = alcohol.
Dashes represent values that were not reported by any participant.
[a]Reported as percentage.
[b]Percentages derived from users (n = 6) and non-users (n = 4) who no longer drink alcohol.

Table 4

Other Substance-Use Characteristics Among Users and Non-Users

	User Status			
	Users (n = 21)		Non-Users (n = 19)	
Substance-Use Characteristics	%	*M* (*SD*)	%	*M* (*SD*)
Have you ever used other substances?				
Yes	57.1		42.1	
No	42.9		57.9	
What other substances have you used?[a]				
Tobacco[b]	83.3	4.50 (5.19)	87.5	2.29 (3.04)
Nicotine[b]	33.3	3.75 (2.99)	12.5	0.00 (N/A)
Stimulants[c]	41.7	15.20 (19.51)	–	–
Inhalants[c]	25.0	15.00 (13.23)	–	–
Depressants[c]	–	–	–	–
Opioids[c]	–	–	–	–
Hallucinogens[c]	50.0	4.17 (3.31)	25.0	2.00 (1.41)
Other: Ecstasy[c]	–	–	12.5	1.00 (N/A)

Table 4 (continued)

Other Substance-Use Characteristics Among Users and Non-Users

	Current User of Other Substances?			
	Users		Non-Users	
	Yes	No	Yes	No
Substance-Use Characteristics	%	%	%	%
Do you currently use tobacco?[d]	50.0	50.0	–	100.0
Do you currently use nicotine?[e]	75.0	25.0	–	100.0
Do you currently use any other drugs?[f]	28.6	71.4	–	100.0
When was the last time you used tobacco/nicotine?[g]				
31d – 6m ago		16.7		–
6m – 1yr ago		16.7		–
1 – 3yrs ago		33.3		25.0
3 – 5yrs ago		33.3		12.5
5+ yrs ago		–		62.5
When was the last time you used any other drugs?[h]				
31d – 6m ago		60.0		–
6m – 1yr ago		80.0		33.3
1 – 3yrs ago		40.0		–
3 – 5yrs ago		–		–
5+ yrs ago		20.0		66.7

Note. Dashes represent values that were not reported by any participant.
[a]Percentages derived from users (n = 12) and non-users (n = 8) who endorsed a history of substance use other than cannabis and alcohol.
[b]M and SD reported as number of years used.
[c]M and SD Reported as total number of uses.
[d]Percentages derived from users (n = 10) and non-users (n = 7) who endorsed a history of tobacco use.
[e]Percentages derived from users (n = 4) and non-users (n = 1) who endorsed a history of nicotine use.
[f]Percentages derived from users (n = 7) and non-users (n = 3) who endorsed a history of any other drug use (e.g., stimulants, inhalants, hallucinogens).
[g]Percentages derived from users (n = 6) and non-users (n = 8) who no longer use tobacco and/or nicotine.
[h]Percentages derived from users (n = 5) and non-users (n = 3) who no longer use any other drugs (note that for users, percentages add up to greater than 100% due to use of multiple drugs within participants).

Table 5

Medical and Psychiatric Characteristics Among Users and Non-Users

	User Status	
	Users (*n* = 21)	Non-Users (*n* = 19)
Medical/Psychiatric Characteristics	%	%
Have you ever been diagnosed with a psychiatric disorder?		
Yes	14.3	15.8
No	85.7	84.2
What were you diagnosed with?		
ADHD	–	10.5
Bipolar disorder	–	5.3
Major depressive disorder	9.1	10.5
Anxiety	4.8	5.3
Have you ever taken any psychiatric medications?		
Yes	9.5	10.5
No	90.5	89.5

Note. ADHD = attention deficit hyperactivity disorder.
Dashes represent values that were not reported by any participant.

Materials

Participant questionnaires.

Initial online screener. Participants completed an initial screener hosted on Qualtrics, an online survey software, to evaluate study eligibility according to the predetermined inclusionary and exclusionary criteria. Participants also provided information regarding cannabis-use characteristics to control for such variables when necessary. For example, individuals endorsing a history of cannabis use answered questions regarding age of cannabis use onset, method of ingestion, preferred cannabis composition (THC vs. CBD), current rate of cannabis use (frequency of use [days per week], amount per occasion [in grams], and duration of cannabis use at that rate), prior rate of cannabis use, and number of lifetime uses. Participants also answered questions regarding history of other drug use and alcohol use to control for such variables when necessary. For example, when applicable, they answered questions regarding types of other drugs used, estimated number of uses, and time since their last use. Participants also responded to questions evaluating age of alcohol use onset, current rate of alcohol use (frequency of use [days per week], number of standard drinks per occasion, and duration of alcohol use at that rate), and prior rate of alcohol use.

Secondary participant questionnaire. At the time of participation, qualifying individuals answered additional demographic questions pertaining to age, gender, ethnicity, years of educations, and socioeconomic status. In addition, they answered questions regarding history of psychiatric diagnoses (including type, age of onset, and time since their resolution), history of psychoactive medication (including type, age of onset, time since last use), and history of medical/neurological conditions (including type, age of onset, and time since their resolution) when applicable. Although individuals with a remote head injury may have qualified for participation, follow-up questions regarding history of head injury were not included given that that the cognitive sequelae of mild to moderate traumatic brain injury (TBI) tend to resolve within three to six months (Rabinowitz & Levin, 2014). Further, although severe TBI is associated with long-term cognitive sequelae in up to 65% of patients, less than half (43%) experience cognitive disability for six months or longer (Rabinowitz & Levin, 2014). Moreover, the author anticipated that those with persisting cognitive deficits would be unlikely to participate due to functional limitations, such as difficulty with meal preparation, driving, and financial management (Rabinowitz & Levin, 2014).

Self-report abstinence assessment. Qualifying individuals were asked to complete a self-report abstinence assessment at the conclusion of their participation to control for variations in abstinence that might influence test performance. Of note, both users *and* non-users were asked to estimate the number of years/months/days/hours (when applicable) that have passed since their last use of cannabis to ensure the examiner would remain blind to user status.

Mood questionnaires. Participants also answered questions regarding their mood given the potential impact of mood on neuropsychological performance. Specifically, depressive symptoms have been shown to impact memory performance, particularly immediate recall and total acquisition of verbal information (Kizilbash, Vanderploeg, Curtiss, 2002). Concurrent depressive and anxious symptoms have an even greater effect, impacting the retrieval of verbal information as well (Kizilbash et al., 2002). In addition, Salthouse (2012) found that trait anxiety and depressive symptoms have a significant negative effect on cognitive abilities at the highest level of an organizational hierarchy, or *g*, which represents the variance shared between five first-order abilities, including reasoning, spatial visualization, episodic memory, perceptual speed, and vocabulary.

Beck Depression Inventory – II. The Beck Depression Inventory – II (BDI-II; Beck, Steer, & Brown, 1996) is a brief self-report screener consisting of 21 questions intended to assess depression in individuals aged 13 to 86 years (Strauss, Sherman, & Spreen, 2006). Scores for each question range from 0 to 3, and total scores range from 0 to 63, with higher scores indicating higher levels of depression. The test demonstrates high reliability and validity. Internal consistency is approximately 0.90 and test-retest reliability generally ranges from 0.73 to 0.96 (Wang & Gorenstein, 2013). With regard to validity, correlation coefficients between the BDI-II and the amended BDI (BDI-IA) are adequate to high and range from .66 to .93 (Beck, Steer, Ball, & Ranieri, 1996; Dozois, Dobson & Ahnberg, 1998; Strauss et al., 2006). The BDI-II is also highly correlated with other depression instruments, such as Hamilton Psychiatric Rating Scale for depression (r = .71; Beck, Steer, & Brown, 1996) and Depression subscale of the Symptom Checklist-90 (r = .89; Steer, Ball, Ranieri, & Beck, 1997).

State-Trait Anxiety Inventory for Adults. The State-Trait Anxiety Inventory for Adults (STAI-AD; Spielberger, Gorsuch, Lushene, Vagg, Jacobs, 1983) is a brief self-report screener consisting of 40 questions that are intended to assess state and trait anxiety in individuals 16 years and older. Scores for each question range from 1 to 4, with higher scores indicating higher levels of anxiety. The test demonstrates good reliability, with internal consistency coefficients ranging from .86 to .95 (Spielberger et al., 1983). Further, test-retest coefficients generally range from .65 to .89 (Spielberger, 1989; Spielberger et al., 1983). With regard to validity, the STAI is highly correlated with the Taylor Manifest Anxiety Scale (r = .73) and Cattell and Scheier's Anxiety Scale Questionnaire (r = .85; Julian, 2011).

Eyewitness materials.

Event. Participants viewed a simulated crime video, hereafter referred to as the "airport video," which was obtained with permission from the producer, G. Wells (personal communication, March 29, 2016). The video is 90 seconds in length and played without sound. The video first depicts the outside of a building with a white shuttle bus driving by. The camera moves toward the building through a revolving door, where it becomes apparent that the building is an airport (i.e., there are gate signs, a TV monitor displaying departure flight schedules, and flight logos). The video then depicts six people standing in a line to check their baggage. The camera zooms in on the culprit, who is the second person in line, and maintains a profile view for 10 seconds. The first and third person in line are also visible in the frame. The camera zooms out after those 10 seconds, and the culprit picks up his luggage and lets two individuals ahead of him. The culprit is then shown switching his luggage with that of the individual directly ahead of him. The camera again zooms in on the profile view of the culprit's face. The culprit then turns to walk out of the line, displaying a full view of his face for approximately 5 seconds as he walks toward the camera and out of the frame. The inexplicit nature of the video allows the witness to compose any number of stories about the event (e.g., drugs, bomb; G. Wells, personal communication, April 1, 2016).

Although several researchers call into question the ecological validity of simulated crime videos, the video-event method remains popular in the eyewitness literature (Wells & Penrod, 2011). Videos are easily administered and far less costly in comparison to live staged events. More importantly, however, research indicates that eyewitness accuracy is similar between individuals, regardless of whether the crime was witnessed live or on video (Pozzulo, Crescini, & Panton, 2008). Further, Ihlebaek, Løve, Eilertsen, and Magnussen (2003) found similar patterns of memory errors under both viewing conditions; however, those who witnessed a crime on video provided more details with greater accuracy. Despite the aforementioned performance differences and obvious distinctions between simulated videos and live events (which are three dimensional and more likely to be emotionally evocative) the use of videos should not be disregarded in research (Wells & Penrod, 2011). Ultimately, laboratory studies aim to identify cause-and-effect relationships (Wells & Quinlivan, 2009), which necessitates adequate control over variables. Thus, simulated crime videos are sometimes preferred over live staged events given the consistency they allow across participants (Wells & Penrod, 2011).

Lineup identification task. Target-present and target-absent lineups were also obtained with permission from the producer, G. Wells (personal communication, March 29, 2016). The target-present lineup consisted of six color photos, five fillers and the culprit, the standard method for lineup construction. The fillers were selected based on their match to the culprit's description (G. Wells, personal communication, April 4, 2016). The target appears as the second photo in the lineup, which is arranged in two rows of three photos. The target-absent lineup consisted of five color photos, which include the same five fillers with the culprit removed. This method is referred to as the "removal-without-replacement" technique, which is sometimes preferred in research to avoid the unpredictable effects that the replacement filler may have on the lineup results (Wells & Penrod, 2011).

Neuropsychological tests. The neuropsychological battery included the California Verbal Learning Test – II (CVLT-II), the Rey-Osterrieth Complex Figure Test (ROCFT), Symbol Span from the Wechsler Memory Scale – Fourth Edition (WMS-IV), Digit Span from the Wechsler Adult Intelligence Scale – Fourth Edition (WAIS-IV), the Trail Making Test (TMT) of the Halstead-Reitan Neuropsychological Battery, and the Test of Premorbid Functioning (TOPF) from the Advanced Clinical Solutions (ACS) for the WAIS-IV and WMS-IV. Performance validity was measured using the Test of Memory and Malingering (TOMM) as well as embedded measures of performance validity such as the Forced Choice (FC) subtest of the CVLT-II and Reliable Digit Span (RDS).

California Verbal Learning Test – II. The CVLT-II (Delis, Kramer, Kaplan, & Ober, 2000) provides a thorough assessment of verbal learning and memory in individuals aged 16 to 89 years. It is both quantity- and process-oriented, clarifying individual learning strategies, vulnerability to interference, and other process-related variables (Strauss et al., 2006). The CVLT-II was standardized utilizing a large U.S. Census-matched sample (N = 1,087) and is considered a reliable and valid assessment of verbal memory (Delis et al., 2000). Specifically, internal consistency coefficients range from .79 to .96 and test-retest correlations range from .27 to .88. With regard to validity, correlation coefficients between the CVLT and CVLT-II are adequate to high and range from .63 to .86 (Delis et al., 2000).

To begin the assessment, the administrator reads aloud List A, which contains a set of 16 target words evenly distributed amongst four semantic categories. Immediately following the presentation of words, the participant is asked to recall as many words as they can remember, thus providing an index of immediate verbal recall. This procedure is completed a total of five times to establish the participant's learning curve.

Subsequently, the administrator reads aloud a list of interference (List B), which is comparable to List A (16 words evenly distributed across four semantic categories), and provides another measure of immediate recall. Next, the participant is asked to freely recall words from List A (short-delay free recall), followed by a semantically-cued recall task (short-delay cued recall). At the conclusion of a 20-minute delay, the participant engages in an additional free and cued recall task (long-delay free recall and long-delay cued recall). Across all trials, the administrator makes note of any repetitions or intrusions that occur during recall.

Following the free and cued recall components of the test, the participant completes a yes/no recognition task. Specifically, the administrator presents 48 words one at a time and the participant provides a "yes" or "no" response to indicate whether the word was from List A. The task is comprised of 16 List A target words and 32 distractor words (including all 16 List B words and 16 additional words). Accurate responses are recorded as recognition hits, while inaccurate responses are recorded as false positive errors. This information is then used to calculate the total recognition discriminability, or one's ability to correctly distinguish between all target and distractor words.

The last portion of the CVLT-II is the FC subtest, which occurs after an additional 10-minute delay. During this task the participant is presented with two words, a target word from List A and a distractor word that differs in phonetic and semantic quality. The participant is tasked with identifying the word from List A. Given that performance on this task is typically without error, this portion of the test may be used as an indicator of performance validity (Bauer, Yantz, Ryan, Warden, & McCaffrey, 2005; Delis et al., 2000; Root, Robbins, Chang, & Van Gorp, 2006). When using a cutoff score of 15, the FC subtest correctly identifies 60% of individuals with poor effort and 81% of individuals with adequate effort, suggesting greater specificity rather than sensitivity (Root et al., 2006).

Rey-Osterrieth Complex Figure Test. The ROCFT (Osterrieth, 1944; Rey, 1941) assesses visual-spatial constructional ability and visual memory in individuals aged 6 to 89 years. This test is particularly unique in that it also provides a wealth of information pertaining to basic skills, such as perceptual and motor functioning, and more abstract abilities, such as planning and organization. The ROCFT was standardized utilizing a sample of 601 individuals and demonstrates adequate reliability and validity as a measure of visual-spatial construction and memory (Strauss et al., 2006). Internal reliability coefficients range from greater than .60 to greater than .80 and test-retest correlations range from .76 to .89 (Meyers & Meyers, 1995). The test also demonstrates convergent and discriminant validity with significant intercorrelations ranging from -1.0 to .88. However, the test's validity as a measure of executive functions is less established (Strauss et al., 2006).

In the first portion of the assessment, the administrator displays an image of a complex geometric design and the participant is asked to copy the design as accurately as possible. There is no time limit on the reproduction of the drawing, however, the administrator keeps track of how long it takes the participant to complete the copy for qualitative purposes. The design stimulus and copy are then removed from the participant's view and the participant completes a brief filler task that takes approximately 3 minutes. Subsequently, the participant is asked to draw the figure from memory. This immediate recall provides a measure of incidental learning and memory given that the participant is not explicitly told to remember the figure at any point. Following a 30-minute delay, the participant is again instructed to recall the figure.

Of note, the administrator simultaneously reproduces the participant's drawing during each condition, noting the order in which elements are drawn. This allows the administrator to qualitatively assess the participant's planning and organizational approach to drawing the figure.

The delayed recall drawing is followed by a recognition task consisting of 24 designs spread across four pages. The participant is instructed to circle the designs that were part of the original complex figure. Twelve of the designs are part of the original figure and 12 designs serve as distractors. Given that eight of the distractor designs are clearly distinct from the original complex figure (atypical recognition errors), this recognition task may assist in the detection of suboptimal effort (Blaskewitz, Merten, & Brockhaus, 2009; Lu, Boone, Cozolino, & Mitchell, 2003). In particular, a combination score, which is calculated utilizing an individual's copy, true positive recognition, and atypical recognition scores, may help to distinguish individuals with suspect effort (Lu et al., 2003).

At the end of the assessment, the administrator scores the participant's copy, immediate recall, and delayed recall of the figure. Although there are many scoring systems, many of the scoring protocols emphasize accuracy (i.e., number of correct details recalled) rather than quality (i.e., symmetry, organization, fragmentation; Strauss et al., 2006). The Rey-Osterrieth 36-point scoring system is one of the most commonly used protocols and includes 18 scoring elements (Meyers & Meyers, 1995; Strauss et al., 2006). Each element can earn a maximum of 2 points for accuracy and placement. Only 1 point is awarded if the element is flawed with regard to accuracy or placement (e.g., the detail is accurately drawn but incorrectly placed). Only half of a point is awarded if the element is inaccurately drawn and placed, but recognizable. A score of zero is assigned if the element is not recognizable or omitted entirely.

Wechsler Memory Scale – Fourth Edition Symbol Span. The Symbol Span subtest from the WMS-IV (Wechsler, 2009b) is a measure of visual working memory for individuals aged 16 to 90 years. The assessment was standardized utilizing a broad normative sample (N = 1,400) and is considered both reliable and valid (Wechsler, 2009b). In particular, unlike other visual assessments that can be verbally mediated to improve performance, Symbol Span is thought to rely primarily on mental imagery (Wechsler, 2009b). The average internal consistency reliability coefficient for this subtest in individuals aged 16-69 is .88. Symbol Span also demonstrates a test-retest coefficient of .72 and is moderately correlated (r = .43) with the Visual Working Memory Index (Wechsler, 2009b).

During the assessment, the participant views a target symbol (or several target symbols) for 5 seconds and is asked to memorize the design from left to right. The participant is then shown a separate page containing the target symbols dispersed amongst several distractor symbols. The participant is tasked with identifying the target symbols in the order that they appeared on the previous page. The task increases in difficulty as the participant progresses and is discontinued following four consecutive imperfect scores. Participants earn 2 points for identifying all target symbols in their correct sequence. Participants earn 1 point for identifying all target symbols in an incorrect sequence. Zero points are awarded if the participant does not accurately recall the target symbols.

Wechsler Adult Intelligence Scale – Fourth Edition Digit Span. The WAIS-IV subtests (Wechsler, 2008) are intended for use with individuals aged 16 to 90 years. The WAIS-IV was standardized using an extensive normative reference group ($N = 2{,}200$) and its reliability and validity are well-established (Wechsler, 2008).

The Digit Span subtest from the WAIS-IV (Wechsler, 2008) is a measure of simple auditory attention and working memory. It has an average internal consistency reliability coefficient of .93 and a test-retest correlation of .83. In addition, it is highly correlated with the Working Memory Index (r = .90). The WAIS-IV Digit Span subtest is also correlated (r = .75) with the WAIS-III version (Wechsler, 1997). These findings suggest that this subtest is both a reliable and valid measure of working memory. In its most simple form, Digit Span Forward, the participant is read several numbers at a rate of one digit per second and is asked to repeat the numbers aloud exactly as they were read. Subsequently, the administrator presents Digit Span Backward, during which the participant is asked to repeat the numbers in backward order (e.g., the correct response to “1-2-3” is “3-2-1”). During the last variation, Digit Span Sequencing, the participant is asked to repeat the numbers in ascending order from lowest to highest (e.g., the correct response to “2-3-1” is “1-2-3”). Each variation of the Digit Span subtest becomes progressively more difficult through the inclusion of additional numbers. However, prior to progressing to longer number sequences, the participant is presented with two trials of equal length and must accurately repeat at least one of the trials. Each variation of the subtest is discontinued if the participant earns a score of zero on both trials of a given length.

Digit Span performance may also be used as an embedded indicator of performance validity. In particular, Greiffenstein, Baker, and Gola (1994) introduced RDS as measure of performance validity, which is obtained by summing the longest digit span performed without error across two trials for the forward and backward conditions. For example, if an individual passed both trials for five digits forward and both trials for four digits backward, but failed one trial for six digits forward and one trial for five digits backward, they would earn an RDS score of 9 (5 forward + 4 backward = 9; Greiffenstein et al., 1994). Traditionally, however, RDS is used to assess performance validity using the WAIS – Revised (WAIS-R) and the WAIS – Third Edition (WAIS-III; Young, Sawyer, Roper, & Baughman, 2012). More recently, Young et al. (2012) aimed to validate RDS using the WAIS-IV, as well as RDS-Revised (RDS-R), which is a modified version of RDS that includes the sequencing trial. Overall, the authors found that with an RDS cutoff score of ≤ 6 and an RDS-R cutoff score of ≤ 10, the test demonstrated modest sensitivity (.24 and .32, respectively) and good specificity (.92 and .89, respectively) with regard to the detection of suboptimal effort (Young et al., 2012).

Trail Making Test. The TMT from the Halstead-Reitan Neuropsychological Battery (Reitan & Wolfson, 1993) is a widely used measure of attention, processing speed, and cognitive flexibility for individuals aged 15 and older. The assessment was standardized utilizing multiple normative reference groups (Heaton, Miller, Taylor, & Grant, 2004; Mitrushina, Boone, Razani, D'Elia, 2005; Tombaugh, 2004) and demonstrates adequate reliability and validity (Strauss et al., 2006). Test-retest reliability has ranged from somewhat poor for Part A (r = .55), but adequate for Part B (r = .75; Bornstein, Baker, & Douglass, 1987) to high for Part A and B (r = .79 and r = .89, respectively; Dikmen, Heaton, Grant, & Temkin, 1999). The TMT also demonstrates adequate alternate-form reliability (r = .89 and .92 for Part A and Part B, respectively; Charter, Adkins, Alekoumbides, & Seacat, 1987). Furthermore, Part A and Part B are moderately correlated with each other (r = .31 to .66), suggesting the measurement of similar, yet slightly different functions (Pineda & Merchan, 2003; Royan, Tombaugh, Rees, & Francis, 2004).

The test consists of two components, Trails A and Trails B, which require varying degrees of cognitive skill. The participant is first provided a sheet of paper containing Trails A, which displays a series of randomly placed circles numbered 1 through 25. Beginning at number 1, the participant must connect the circles in sequential order until they reach number 25, which marks the end of the trail. Trails B, the more difficult of the tasks, presents that participant with circles numbered 1 through 13, which are scattered amongst circles lettered A through L. The participant is again directed to connect the circles, this time alternating their connection between numbers and letters (e.g., 1-A, A-2, 2-B, and so on) until they reach the number 13, which marks the end of the trail.

A score for each task is calculated using the total time (in seconds) to complete the trail. Thus, the participant is instructed to complete the trail as quickly as possible without making mistakes. However, if a mistake is made, the administrator redirects the participant to their last correctly connected circle, thereby increasing the total time to complete the task and reducing the quality of their score.

Test of Premorbid Functioning. The TOPF from ACS (Wechsler, 2009a) is a measure that estimates premorbid intelligence for individuals aged 16 to 90 years. The test was developed utilizing a premorbid prediction sample comprised of the WAIS-IV standardization group and an oversample intended to adequately represent ethnicity and education (Wechsler, 2009a). Ultimately, the test demonstrates good reliability and validity. In particular, the TOPF is highly correlated with the WAIS-IV Verbal Comprehension Index (r = .75) and Full-Scale IQ (r = .70), supporting the use of this measure in the estimation of premorbid intellect (Wechsler, 2009a). The test also demonstrates adequate correlations with years of education (r = .55) and occupation (r = .45; Wechsler, 2009a). Moreover, the TOPF is thought to be relatively impervious to the effects of dementia or brain injury (Wechsler, 2009a).

To begin the assessment, the administrator presents the participant with the TOPF Word Card, which displays 36 words on the front and 34 on the back for a total of 70 words. The words are selected specifically due to their unusual grapheme-to-phoneme translation (e.g., gnat; Wechsler, 2009a). The individual is asked to read down the list aloud, beginning at item one, and is instructed to continue on to subsequent columns until they have read all 70 words. Individuals are encouraged to attempt pronunciation, even if they are unsure. The administrator scores each pronunciation as the words are read and totals the number of correctly pronounced words.

Test of Memory and Malingering. The TOMM (Tombaugh, 1996) is a PVT used to assess the feigning or exaggeration of memory dysfunction in individuals aged 5 years and older. The assessment has also been standardized utilizing several normative samples (Teichner & Wagner, 2004; Tombaugh, 1997) and is a valid assessment of feigned impairment or suboptimal effort (Strauss et al., 2006). Less is known regarding the test's reliability; however, the test is thought to be internally consistent, with Tombaugh reporting coefficient alphas of .94, .95, and .94 across the three trials (as cited in Strauss et al., 2006). In addition, when utilizing a cutoff score of 45 on Trial 2, specificity and sensitivity rates are greater than 90% and 84% (respectively) for feigned vs. genuine TBI, aphasic, and cognitively impaired patients (Rees, Tombaugh, Gansler, & Moczynski, 1998; Tombaugh, 1997).

The administrator first presents two learning trials, which are followed by a 15-minute delay and an optional retention trial. During Trial 1, the administrator shows the participant 50 basic drawings of common objects, each on a separate page, at a rate of 3 seconds per page. After all images are shown, the administrator presents a forced-choice recognition task composed of 50 separate pages, each containing a target image paired with a new image. The participant must indicate which of the images is the target image shown previously. For each recognition page, the administrator provides corrective feedback, indicating whether the participant has made a correct or incorrect selection. Immediately following Trial 1, the administrator presents Trial 2, in which the images are identical to Trial 1 but are presented in a different order. Fifteen minutes following Trial 2, the administrator may choose to present the Retention Trial. The Retention Trial solely consists of the forced-choice recognition task and is most commonly administered when a participant earns a score below 45 on Trial 2, indicating questionable effort; however, it may also be administered to substantiate findings from Trials 1 and 2. In the present study, the Retention Trial was not administered if participants earned a 45 or greater on Trial 2.

Procedure

Participants were recruited through the use of flyers, which were posted at various locations throughout the community (i.e., coffee shops, parks, grocery stores, cannabis dispensaries, undergraduate campuses) and online on Craigslist and Facebook. When necessary, the researcher obtained site approval prior to posting flyers for recruitment purposes. For example, the researcher contacted the institutional review board (IRB) at designated undergraduate universities to ensure that recruitment of their students was permitted. With IRB approval, the researcher requested that undergraduate psychology professors share the recruitment flyer with their students through email. The recruitment flyer advertised the general purpose of the study without spoiling individuals to the eyewitness component (i.e., "this study aims to assess the cognitive effects of cannabis") and indicated that both cannabis users and non-users were needed for participation. Length of time to complete the study (1.5-2 hours) was also advertised, along with the opportunity for $50 compensation for participation. Interested individuals were directed to complete the initial participant screener for eligibility determination through the use of a hyperlink or the quick response (QR) code displayed on the flyer. Eligible respondents were contacted by phone or email to schedule a testing session. Of note, the examiner did not review online screeners in order to remain blind to participant user status.

Upon arrival for their scheduled testing session, the researcher provided the participant with an informed consent form and jointly reviewed the critical components to ensure understanding. If consent was provided, the examiner then privately recorded whether they believed the participant was a user or a non-user. This judgment was collected to assess the role of expectancy effects with regard to neuropsychological or eyewitness performance when utilizing examiners blind to user status (Hirst et al., 2017).

Subsequently, the researcher conducted a basic field sobriety test to ensure that the participant had not recently consumed cannabis or alcohol. Specifically, the researcher asked the participant to balance for 30 seconds with one foot raised approximately 6 inches off the ground, a method that is commonly used to detect intoxication as part of the Standardized Field Sobriety Test (National Highway Traffic Safety Administration [NHTSA], 2013). All participants passed the field sobriety test.

Upon successful completion of the field sobriety test, the participant was permitted to proceed with the study. The examiner then completed the secondary questionnaire with the participant to record further information regarding their demographic, psychiatric, and medical history. The participant then completed two self-report mood questionnaires. If the participant was found to be at risk for suicide (a score of 2 or 3 on question 9 of the BDI-II) OR if the participant reported extreme distress (scores of 29-63 on the BDI-II or scores of 39-40 on the STAI-AD state anxiety scale), the researcher was to consult with one of the on-call licensed clinical psychologists. No one presented with imminent risk; however, instances of imminent risk would warrant discontinuation of the study and a referral to an appropriate clinical professional or Emergency Services (911).

After completion of all questionnaires, the researcher read a script to begin the evaluation. To replicate the eyewitness experience as accurately as possible, the participant was not told that they would be watching a crime beforehand, as real-world eyewitnesses are often unaware that they are about to witness a crime (Wells & Penrod, 2011). Rather, the participant was told that the study would begin by "assessing your impression of events," as is recommended in video-event research (Wells & Penrod, 2011). The researcher then directed the participant's attention toward a computer screen where they watched a simulated crime video. After viewing the video, the participant completed the TMT as a brief filler task. This was intended to approximate real life witnessing conditions in which delays are likely to occur prior to providing a statement. The participant then provided a series of statements on Qualtrics. First, they freely recalled as many details of the criminal event as possible using a blank text box (Appendix C). Next, the participant answered a set of open-ended cued-recall questions to elicit further information about the video (Appendix C). This is similar to a police interview in which an eyewitness might be asked to provide additional details that were not included in their initial statement.

Finally, the participant completed a lineup identification task, which was also hosted on Qualtrics. However, prior to viewing the lineup, participants were presented with a practice trial (without photos) to ensure they understood how to respond to the task. Participants then viewed either a simultaneous target-present (Appendix D) or simultaneous target-absent lineup (Appendix E) on the computer, which the researcher randomly determined beforehand by flipping a coin. A simultaneous presentation was chosen because it allows for greater experimental control, and accuracy differences between simultaneous and sequential lineups are relatively small (Steblay et al., 2011). The participant was then asked to choose the culprit from the lineup or indicate that the culprit was not present, regardless of lineup condition (target-present and target-absent). In addition, Qualtrics was configured to record participants' response latency for their lineup selection. Subsequently, participants provided a confidence rating for their selection, which was presented on an 11-point scale (0%, 10%, 20%...100%) with the anchors 0% (not at all confident), 50% (somewhat confident), and 100% (entirely confident that the selection is correct). This confidence scale was selected due to its inclusion in previous research assessing confidence-accuracy relationships (i.e., Brewer & Wells, 2006; Palmer, Brewer, et al., 2013; Sauer et al., 2010).

After completion of the eyewitness identification task, the researcher administered a battery of neuropsychological tests to assess participants' cognition and performance validity. At the end of the test battery, participants were asked to privately write down a self-report estimate of the length of time that has passed since their last use of cannabis. After providing this estimation, individuals were fully debriefed regarding the eyewitness portion of the study. They were then given a $50 American Express gift card for participation and provided contact information should they have any questions regarding their participation or the outcome of the study.

Data Coding

ROCFT scoring. Forty-five percent of the total sample's ROCFT Copy, Immediate Recall, and Delayed Recall figures were double-scored in a blind manner. For this subset, the author resolved discrepancies with the assigned double-scorer to obtain total scores for the three trials, which were utilized in the final dataset. The author then calculated interrater reliability between the two scorers' original total scores using intraclass correlation coefficients (ICC). A high degree of reliability was found between the two raters' total Copy score, ICC(1, 2) = .94, 95% confidence interval [CI; 0.83, 0.98], *F*(17,

18) = 15.70, $p < .001$, total Immediate Recall score, ICC(1, 2) = .98, 95% CI [0.94, 0.99], $F(17, 18) = 42.44$, $p < .001$, and total Delayed Recall score, ICC(1, 2) = .99, 95% CI [0.97, 1.00], $F(17, 18) = 77.26$, $p < .001$. Given the significant correlations between scorers, the author independently scored the remainder of the figures for use in the final data set.

Qualitative eyewitness data. Prior to coding the qualitative eyewitness data, the author created a coding scheme listing details from the airport video. Details were added gradually when participants provided information that was not included in the original coding scheme. The author then segmented participants' recollections into scorable units and compared each response to the master-list and with the video recording as needed. For example, the recollection, "The man swapped their luggage and walked off" would be divided into four units, "The man/swapped/their luggage/and walked off." Each detail was then evaluated for its specificity (i.e., was it a unique piece of information) and was allotted one point if it was correct (e.g., the suitcase was black) or incorrect (e.g., the suitcase was red); correct and incorrect items were tallied separately. Of note, half points were allotted as necessary in the cued recall condition for details that were generally accurate but lacking specificity (e.g., answering, "departures" when asked "In what section of the airport did the event take place?", rather than the more specific "baggage check-in line"). Details were also scored as incorrect if they were confabulated (e.g., "he quickly headed to the exit" when the video shows the culprit walking out of view, but not explicitly toward an exit). When details were repeated, subjective (e.g., the culprit looked suspicious), or could not be reliably scored because that information was unavailable (e.g., "The guy at the front of the line was a teenager, between age 14 or 15"), they were not scored for accuracy and therefore were not counted toward the total number of details recalled (i.e., number of accurate and inaccurate details collapsed across free and cued recall conditions). Of note, estimates regarding culprit characteristics were scored as correct if age was ± 2 years, if height was ± 2 inches, and weight was ± 5 pounds, consistent with Yuille and Cutshall's (1986) procedures. In addition, when recollections included qualifiers regarding degree of certainty (e.g., "he *might* have been wearing a gray shirt"), the information was scored without consideration of the qualifier (Yuille & Cutshall, 1986). Overall accuracy was then calculated as a percentage similar to Yuille et al.

(1998; i.e., total number of accurate details divided by the total number of accurate and inaccurate details recalled).

Planned Statistical Analyses

Power. As mentioned previously, an *a priori* G* power calculation for MANOVA global effects suggested that approximately 42 participants would be needed to achieve sufficient power (.80), with two outcome variables, an alpha of .05, and a medium effect ES of $f^2 = 0.25$. Because the sample size was 40, the author calculated post-hoc power analyses to determine achieved power as needed.

Demographic differences. Independent-samples *t*-tests were planned to assess for demographic differences between users and non-users with regard to continuous variables of interest (i.e., age, years of education, premorbid intelligence) and chi-square tests of association were planned for categorical variables (i.e., gender, ethnicity). The author also planned to include variables in which groups differed significantly as covariates using a one-way multivariate analyses of covariance (MANCOVA). Variables were also included as covariates if they significantly predicted neuropsychological or eyewitness performance.

Effort test performance. A one-way multivariate analysis of variance (MANOVA) was planned to compare effort test performance between users and non-users, with user status as the independent variable and scores on effort measures as the dependent variables.

Effects of cannabis use status on neuropsychological performance. A one-way MANOVA was planned to compare users and non-users' performance on neuropsychological measures (e.g., verbal and visual recognition tasks) with user status as the independent variable and total scores as the dependent variables (Hypothesis 1).

Effects of user status on eyewitness tasks. A one-way MANOVA was planned to assess the effects of user status on number of crime video details recalled and the accuracy of details recalls (Hypothesis 2). A binomial logistic regression was planned to assess the effects of user status and lineup condition on lineup identification accuracy, with user status, lineup condition, gender, and years of education as predictor variables and lineup identification accuracy as the outcome variable (Hypothesis 3).

The author planned to use version 3.3 of Hayes' (2017) PROCESS macro for SPSS to evaluate whether performance on the ROCFT RT (T-score) mediates the relationship between user status and lineup identification accuracy (Hypothesis 4; see Figure 1). This program utilizes ordinary least squares (OLS) regression to estimate regression coefficients *a*, *b*, and *c'*. In this model, the mediator (ROCFT RT) is proposed to explain the relationship between the independent variable (user status) and the outcome variable (lineup identification accuracy). User status is proposed to influence performance on the ROCFT RT (*a*), which impacts lineup identification accuracy (*b*), which represents the indirect effect (*ab*) of user status on lineup identification accuracy through ROCFT RT performance. The direct effect (*c'*) represents the effect of user status on lineup identification accuracy, where ROCFT RT performance is held constant (Rucker, Preacher, Tormala, & Petty, 2011). The total effect (*c*) is obtained through combing the indirect and direct effects.

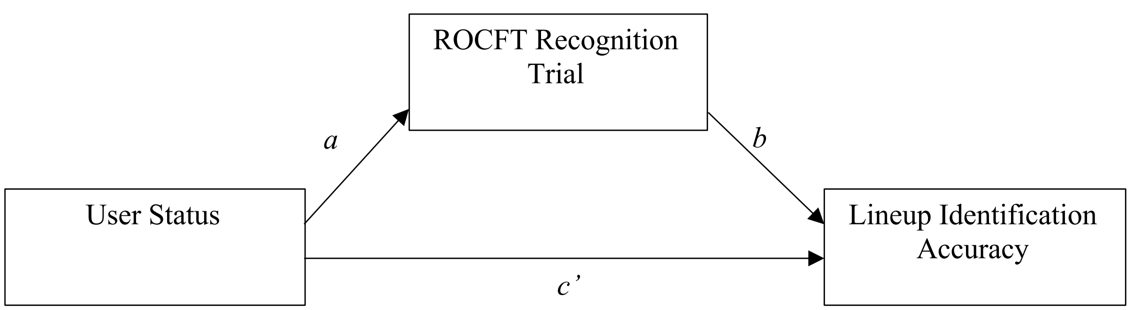

Figure 1. Mediation model for Hypothesis 4.

The PROCESS mediation analysis utilizes bootstrapping, a method of resampling, to estimate the indirect effect (Hayes, 2017). When bootstrapping is performed, the study sample size *n* is treated as a minute representation of the sampled population. Observations from the sample are then "resampled with replacement," and the test statistic is calculated utilizing the newly derived sample of size *n,* which is generated from the resampling process (Hayes, 2017, p. 97). Resampling generally occurs thousands of times to empirically construct a representation of the sampling distribution of the indirect effect, which is used to construct the confidence interval for ${}_{T}a_{T}b$. This method is beneficial because there are no assumptions regarding the shape of the *ab* sampling distribution, which is useful in smaller samples where non-normality of the *ab* sampling distribution is more likely to occur (Hayes, 2017). In addition, bootstrapping is recommended over other approaches as it maintains a higher level of power while reasonably controlling for Type I errors (Preacher & Hayes, 2008).

CHAPTER III

RESULTS

Demographic Features of Users and Non-Users

Independent-samples *t*-tests tested for demographic differences between users and non-users on continuous variables of interest and chi-square tests of association were used for categorical variables of interest (see Table 6). Of note, chi-square analyses produced using a 2x2 table are reported using Yates' Correction for Continuity (which serves to compensate for overestimations of chi-square when produced using a 2x2 table; Pallant, 2010). In addition, where expected cell frequencies were less than 5 in a 2x2 table, Fisher's exact test is reported. Cannabis users had significantly fewer years of education than non-users (p = .010, d = -0.87). Therefore, years of education was included as a covariate when necessary. Conversely, users and non-users did not differ with regard to estimated premorbid IQ, age, gender, or handedness (of note, one ambidextrous person was excluded from this analysis). Given the distribution of racial groups, the author grouped participants into those who self-identified as White (42.9% and 26.3% of users and non-users, respectively) and those who self-identified as another racial group for the purpose of this analysis. Cannabis users and non-users did not differ with regard to their racial identification. Similarly, given the distribution of annual household income, the author grouped participants in those who reported earning between less than $10k and $50k and those who reported earning between $50k and $150k or more. Cannabis users and non-users did not differ with regard to their annual household income.

Table 6

Demographic Differences Among Users and Non-users.

	Users (n = 21)		Non-Users (n = 19)				
Demographic Characteristics	*M*	*SD*	*M*	*SD*	*t*	*p*	*d*
Age	27.24	7.25	31.47	7.14	1.86	.071	-0.59
Education	14.52	1.66	16.00	1.76	2.73	.010	-0.87
Premorbid IQ	106.38	12.34	107.53	11.82	0.30	.767	-0.10

Table 6 (continued)

Demographic Differences Among Users and Non-users.

	Users (n = 21)		Non-Users (n = 19)			
Demographic Characteristics	n	%	n	%	χ^2	p
Gender					0.45	.504
Male	11	52.4	7	36.8		
Female	10	47.6	12	63.2		
Handedness						>.999[a]
Right	18	90.0	18	94.7		
Left	2	10.0	1	5.3		
Race/Ethnicity					0.58	.445[b]
White	9	42.9	5	26.3		
Hispanic/Latino	5	23.8	2	10.5		
Black	3	14.3	1	5.3		
Asian	3	14.3	6	31.6		
Hawaiian/Pacific Islander	–	–	1	5.3		
Two or more races	1	4.8	4	21.1		
Income					0.07	.793[c]
< \$10k to \$30k	9	42.9	4	21.1		
\$30k to \$60k	7	33.3	6	31.6		
\$60k to \$90k	1	4.8	1	5.3		
\$90k to \$150k+	3	14.3	5	26.3		
Did not to disclose	1	4.8	3	15.8		

Note. Dashes represent values that were not reported by any participant.
[a]Reported as Fisher's exact test.
[b]Chi-square analysis performed on racial groups divided into White vs. non-White.
[c]Chi-square analysis performed on income groups divided into < \$10k to \$50k and \$50k to \$150k+.

With regard to cannabis-use characteristics, users and non-users differed significantly with regard to age of cannabis-use onset, with users reporting an earlier age of onset relative to non-users, $t(31) = 5.60$, $p < .001$, $d = -2.03$. In addition, users and non-users differed significantly with regard to last cannabis use, with users having fewer days of abstinence prior to their evaluation, $t(9) = 2.68$, $p = .025$, $d = -1.41$. Differences between users and non-users with regard to other cannabis-use variables were not examined given the inherent nature of the inclusionary criteria.

With regard to other substance use and psychiatric characteristics, users and non-users did not differ significantly with regard to current alcohol use ($p = .716$), history of other drug use, $\chi^2(1) = 0.40$, p

= .527, history of psychiatric disorder, $p > .999$, or history of psychiatric medication, $p > .999$. Of note, two users reported current other drug use (defined as other drug use in the last 30 days) and one user's self-reported length of abstinence at the time of testing was 2 hours. As a result, main analyses were conducted with and without these individuals to determine whether their inclusion impacted study findings. Findings from analyses excluding these individuals did not differ from findings including the full sample, with the exception of the final mediation analysis, in which case results for all samples are reported. Otherwise, the results reported herein include the full sample. Additionally, users and non-users did not differ with regard to current self-reported depressive or anxious symptoms, as measured by the BDI-II, $t(30) = 0.16$, $p = .873$, $d = -0.06$, and STAI State, $t(30) = 1.02$, $p = .317$, $d = -0.36$, and Trait, $t(30) = 0.09$, $p = .932$, $d = -0.03$, indices.

PVT Performance

A MANOVA was run to determine the effect of user status on measures of performance validity. Three PVTs were assessed: CVLT-II FC Recognition, RDS, and TOMM Trial 2. Preliminary assumption checking revealed that data violated the assumption of normality, as assessed by Shapiro-Wilk test ($p >$ .05). Normality could not be achieved with transformation of variables. Of note, the significant negative skew observed in these data is consistent with expectation, as these measures are easily passed among those putting forth good effort (Bigler, 2014). There were also univariate outliers on the CVLT-II FC and TOMM, as assessed by inspection of a boxplot, and one multivariate outlier, as assessed by Mahalanobis distance ($p < .001$). There was not a linear relationship between variables, as assessed by scatterplot; however, consistent with assumptions, there was no multicollinearity. Homogeneity of variance-covariance matrices could not be assessed by Box's M test, as there were fewer than two nonsingular cell covariance matrices. Differences between users and non-users on the combined dependent variables were not statistically significant, $F(3, 36) = 1.75$, $p = .175$; Wilks' $\Lambda = 0.87$; partial $\eta^2 = 0.13$. Power was determined to be 0.71, 0.72, and 0.28 for the CVLT-II, RDS, and TOMM respectively, where ES (f^2) = 0.25, 9.26, and 9.08, respectively (calculated as $\sqrt{[\eta^2 / 1 - \eta^2]}$). Although statistical analyses were underpowered, it is worth noting that all participants passed all measures of performance validity, with the exception of one non-user who produced a failing RDS score of 6. Of note, Cohen's *d* was determined to be $d_{CVLT\text{-}II} = 0.48$, $d_{RDS} = -0.66$, and $d_{TOMM} = -0.19$, suggesting that even if significant group differences were observed, RDS is the only measure in which a potentially meaningful effect exists, as user status had a positive effect on CVLT-II FC performance and a negligible negative effect on TOMM performance.

Effects of Cannabis-Use Status on Neuropsychological Performance

A MANOVA was run to determine the effect of user status on two measures of neuropsychological performance: CVLT-II Yes/No Recognition Discriminability (*z*-score) and ROCFT Recognition Trial (RT) Total Correct (T-score; Hypothesis 1). Gender and education were not significant predictors of CVLT-II Yes/No Recognition Discriminability ($p = .675$ and $p = .132$, respectively; $F(2, 37) = 1.36$, $p = .268$, adj. $R^2 = .02$) or ROCFT RT ($p = .352$ and $p = .116$, respectively; $F(2, 37) = 1.59$, $p = .217$, adj. $R^2 = .03$) and were therefore not included as covariates. Preliminary assumption checking revealed that data violated the assumption of normality, as assessed by Shapiro-Wilk test ($p > .05$). Normality could not be achieved with transformation of variables. There was one univariate outlier, as assessed by inspection of a boxplot; however, there were no multivariate outliers, as assessed by Mahalanobis distance ($p > .001$). There was a linear relationship between variables, as assessed by scatterplot; there was no multicollinearity ($r = .50$, $p = .001$). There was homogeneity of variance-covariances matrices, as assessed by Box's M test ($p = .758$). Results failed to disprove the null hypothesis that users' and non-users' performance on verbal and visual recognition tasks is similar, $F(2, 37) = 0.02$, $p = .981$; Wilks' $\Lambda = 1.00$; partial $\eta^2 < 0.01$ (CVLT-II Yes/No Recognition: $M = 0.21$, $SD = 0.92$ and $M = 0.16$, $SD = 1.12$, among users and non-users respectively; ROCFT RT: $M = 47.19$, $SD = 11.68$ and $M = 47.16$, $SD = 12.89$, among users and non-users respectively). Of note, power was determined to be 0.14 and 0.05 for CVLT-II and ROCFT, respectively, where ES (f^2) = 0.03 and < 0.01, respectively (calculated as $\sqrt{[\eta^2 / 1 - \eta^2]}$). Again, although statistical analyses were underpowered, Cohen's d was determined to be $d_{CVLT-II} = 0.05$ and $d_{ROCFT} < 0.01$, suggesting that even if significant group differences were observed, such differences would be negligible.

Because length of self-reported cannabis abstinence was a marginally significant predictor of CVLT-II Yes/No Recognition Discriminability performance ($b < -0.01$, $SE < 0.01$, $p = .051$, 95% CI [-0.002, 0.000]; $F(2, 22) = 3.47$, $p = .049$, adj. $R^2 = .17$), a MANCOVA was run to determine whether there were any statistically significant differences between the adjusted means of the independent groups after controlling for this covariate; however, conclusions from test comparisons did not differ, $F(2, 23) = 0.89$, $p = .424$, $d_{CVLT-II} = 0.37$, $d_{ROCFT} = 0.32$; Wilks' $\Lambda = 0.93$; partial $\eta^2 = 0.07$. Of note, age of cannabis-use onset was not a significant predictor of CVLT-II Yes/No Recognition Discriminability ($p = .622$) and neither self-reported abstinence nor age of cannabis-use onset were significant predictors of ROCFT RT performance ($p = .452$ and $p = .999$, respectively; $F(2, 22) = 0.37$, $p = .695$, adj. $R^2 = -.06$).

An exploratory MANOVA was run to determine the effect of user status on CVLT-II Yes/No Recognition Discriminability and ROCFT RT *raw* scores. Gender and education were not significant predictors of CVLT-II Yes/No Recognition Discriminability ($p = .123$ and $p = .079$, respectively; $F(2, 37) = 3.24$, $p = .051$, adj. $R^2 = .10$) or ROCFT RT ($p = .529$ and $p = .245$, respectively; $F(2, 37) = 0.83$, $p = .445$, adj. $R^2 = -.01$) and were therefore not included as covariates. Similarly, age of cannabis-use onset and length of self-reported cannabis abstinence were not significant predictors of CVLT-II Yes/No Recognition Discriminability ($p = .810$ and $p = .104$, respectively; $F(2, 22) = 2.10$, $p = .146$, adj. $R^2 = .08$) or ROCFT RT ($p = .948$ and $p = .396$, respectively; $F(2, 22) = 0.51$, $p = .606$, adj. $R^2 = -.04$) and were therefore not included as covariates. Preliminary assumption checking revealed that data violated the assumption of normality, as assessed by Shapiro-Wilk test ($p > .05$). Normality could not be achieved with transformation of variables. There were four univariate outliers, as assessed by inspection of a boxplot; however, there were no multivariate outliers, as assessed by Mahalanobis distance ($p > .001$). There was a linear relationship between variables, as assessed by scatterplot; there was no multicollinearity ($r = .51$, $p = .001$). There was homogeneity of variance-covariances matrices, as assessed by Box's M test ($p = .897$). Results failed to disprove the null hypothesis that users' and non-users' performance on verbal and visual recognition tasks is similar, $F(2, 37) = 0.07$, $p = .935$, $d_{\text{CVLT-II}} = 0.03$, $d_{ROCFT} = 0.11$; Wilks' $\Lambda = 1.00$; partial $\eta^2 < 0.01$ (CVLT-II Yes/No Recognition: $M = 3.41$, $SD = 0.69$ and $M = 3.39$, $SD = 0.79$, among users and non-users respectively; ROCFT RT: $M = 21.05$, $SD = 1.75$ and $M = 20.84$, $SD = 1.92$, among users and non-users respectively).

An exploratory MANCOVA was also run to determine the effect of user status on CVLT-II Long Delay Free Recall (LDFR; *z*-score) and ROCFT Delayed Recall (DR; T-score). Gender and education were not significant predictors of CVLT-II LDFR ($p = .829$ and $p = .451$, respectively; $F(2, 37) = 0.34$, $p = .717$, adj. $R^2 = -.04$) or ROCFT DR ($p = .697$ and $p = .343$, respectively; $F(2, 37) = 0.59$, $p = .561$, adj. $R^2 = -.02$) and were therefore not included as covariates. Similarly, age of cannabis-use onset was not a significant predictor of ROCFT DR ($p = .858$); however, length of self-reported cannabis abstinence was a significant predictor of ROCFT DR ($b = -0.01$, $SE = 0.01$, $p = .046$, 95% CI [-0.03, 0.00]; $F(2, 22) = 3.08$, $p = .066$, adj. $R^2 = .15$). In addition, age of cannabis-use onset ($b = 0.12$, $SE = 0.05$, $p = .017$, 95% CI [0.02, 0.22]) and length of self-reported cannabis abstinence ($b < -0.01$, $SE < 0.01$, $p = .007$, 95% CI [-0.002, 0.000]) were significant predictors of CVLT-II LDFR, $F(2, 22) = 5.31$, $p = .013$, adj. $R^2 = .26$. As a result, these two cannabis-use variables were included as covariates. Not all pairs of dependent variables and not all of the relationships between the covariates and dependent variables were linearly related, as assessed by visual inspection of a scatterplot. There was homogeneity of regression slopes, as assessed by the interaction terms. There was homogeneity of variances and covariances, as assessed by Box's M test ($p = .512$). There were no univariate outliers in the data, as assessed by standardized residuals greater than ± 3 standard deviations. There were no multivariate outliers in the data, as assessed by Mahalanobis distance ($p > .001$). Residuals were normally distributed, as assessed by Shapiro-Wilk's test (p > .05). Results failed to disprove the null hypothesis that users' and non-users' performance on verbal and visual delayed recall tasks is similar after controlling for age of cannabis-use onset and self-reported cannabis abstinence, $F(2, 20) = 1.79$, $p = .194$, $d_{\text{CVLT-II}} = 0.35$, $d_{\text{ROCFT}} = 0.45$; Wilks' $\Lambda = 0.85$; partial $\eta^2 = 0.15$ (CVLT-II LDFR: $M = 0.09$, $SD = 0.80$ and $M = -0.25$, $SD = 1.28$, among users and non-users respectively; ROCFT DR: $M = 43.82$, $SD = 14.19$ and $M = 37.63$, $SD = 13.15$, among users and non-users respectively).

An exploratory MANOVA was also run to determine the effect of user status on verbal and visual working memory, as measured by Digit Span Backward (DSB; scaled score) and Symbol Span (SS; scaled score). Gender and education were not significant predictors of DSB ($p = .608$ and $p = .108$, respectively; $F(2, 37) = 1.41$, $p = .257$, adj. $R^2 = .02$) or SS ($p = .757$ and $p = .338$, respectively; $F(2, 37) = 0.49$, $p = .615$, adj. $R^2 = -.03$) and were therefore not included as covariates. Similarly, age of cannabis-use onset and length of self-reported cannabis abstinence were not significant predictors of DSB ($p = .374$ and $p = .285$, respectively; $F(2, 22) = 0.70$, $p = .506$, adj. $R^2 = -.03$) or SS ($p = .279$ and $p = .080$, respectively; $F(2, 22) = 1.73$, $p = .200$, adj. $R^2 = .06$) and were therefore not included as covariates. Preliminary assumption checking revealed that data were normally distributed, as assessed by Shapiro-Wilk test ($p > .05$). There was one univariate outlier, as assessed by inspection of a boxplot; however, there were no multivariate outliers, as assessed by Mahalanobis distance ($p > .001$). There was not a linear relationship between variables, as assessed by scatterplot; there was no multicollinearity ($r = .10$ $p = .550$). There was homogeneity of variance-covariances matrices, as assessed by Box's M test ($p = .954$). Results failed to disprove the null hypothesis that users' and non-users' performance on verbal and visual working memory tasks is similar, $F(2, 37) = 1.89$, $p = .165$, $d_{DSB} = -0.61$, $d_{SS} = 0.06$; Wilks' $\Lambda = 0.91$; partial $\eta^2 = 0.09$ (DSB: $M = 10.05$, $SD = 3.09$ and $M = 12.00$, $SD = 3.30$, among users and non-users respectively; SS: $M = 9.81$, $SD = 2.21$ and $M = 9.68$, $SD = 2.45$, among users and non-users respectively).

Effects of Cannabis-Use Status on Eyewitness Performance

Crime video details recalled. A MANOVA was run to determine the effect of user status on two measures of eyewitness memory: total number of crime details recalled and percent of accurate details recalled (which was calculated as a percentage by dividing the number of correctly recalled items by the total number of items reported during the interview [i.e., correct items plus incorrect items]; Hypothesis 2). Preliminary assumption checking revealed that data violated the assumption of normality, as assessed by Shapiro-Wilk test ($p > .05$). Normality could not be achieved with transformation of variables. There was one univariate outlier, as assessed by inspection of a boxplot; however, there were no multivariate outliers, as assessed by Mahalanobis distance ($p > .001$). There was a linear relationship between variables, as assessed by scatterplot; there was no multicollinearity ($r = .51$, $p = .001$). There was homogeneity of variance-covariances matrices, as assessed by Box's M test ($p = .521$). Ultimately, results failed to disprove the null hypothesis that users' and non-users' eyewitness recall is similar, $F(2, 37) = 0.34$, $p = .713$; Wilks' $\Lambda = 0.98$; partial $\eta^2 = 0.02$ (number of details recalled: $M = 43.83$, $SD = 13.26$ and $M = 43.55$, $SD = 9.96$, among users and non-users, respectively; accuracy of details recalled: $M = 84.95$, $SD = 5.59$ and $M = 86.22$, $SD = 6.27$ among users and non-users, respectively). Of note, power was determined to be 0.09 and 0.42 for total details recalled and percentage of accurate details, respectively, where ES (f^2) = 0.01 and 0.11, respectively (calculated as $\sqrt{[\eta^2/ 1 - \eta^2]}$). Again, although statistical analyses were underpowered, Cohen's *d* was determined to be $d_{TotalDetails} = 0.02$ and $d_{Accuracy} = -0.21$, suggesting that even if significant group differences were observed, such differences would be negligible.

Because years of education was a significant predictor of total details recalled ($b = 2.07$, $SE = 0.97$, $p = .039$, 95% CI [0.11, 4.03]; $F(1, 38) = 4.57$, $p = .039$, adj. $R^2 = .08$), a MANCOVA was run to determine whether there were any statistically significant differences between the adjusted means of the independent groups after controlling for education; however, conclusions from test comparisons did not differ, $F(2, 36) = 0.89$, $p = .421$; Wilks' $\Lambda = 0.95$; partial $\eta^2 = 0.05$. Of note, age of cannabis-use onset and self-reported length of cannabis abstinence were not significant predictors of total details recalled ($p = .383$ and $p = .333$, respectively; $F(2, 22) = 0.61$, $p = .553$, adj. $R^2 = -.03$) nor percent of accurate details recalled ($p = .572$ and $p = .484$, respectively; $F(2, 22) = 0.29$, $p = .750$, adj. $R^2 = -.06$) and were therefore not included as covariates.

An exploratory MANOVA was also run to examine gender differences in number and accuracy of eyewitness details recalled. Males and females did not differ significantly on the combined dependent variables, $F(2, 37) = 0.03$, $p = .971$, $d_{Total} = 0.08$, $d_{Accuracy} = 0.03$; Wilks' $\Lambda = 1.00$; partial $\eta2 < 0.01$

(number of details recalled: M = 43.19, SD = 14.80 and M = 44.11, SD = 8.65, among males and females, respectively; accuracy of details recalled: M = 85.45, SD = 5.68 and M = 85.64, SD = 6.17 among males and females, respectively).

Effects of user status and lineup condition on lineup identification accuracy. A binomial logistic regression was used to assess the effects of user status and lineup condition on lineup identification accuracy, with user status, lineup condition, gender, and years of education as predictor variables and lineup identification accuracy as the outcome variable (Hypothesis 3). Of note, age of cannabis-use onset and length of self-reported cannabis abstinence were not significant predictors of lineup identification performance (p = .071 and p = .500, respectively; $\chi^2(4) = 9.45$, p = .051, Nagelkerke R^2 = .42), and were not included in the final model given the reduced sample size with inclusion of these variables (n = 17 and n = 8 among users and non-users, respectively). Cannabis user status, lineup condition, gender, and lineup identification accuracy were dummy coded such that 0 = non-user and 1 = user, 0 = target-absent and 1 = target-present, 0 = female and 1 = male, and 0 = inaccurate and 1 = accurate, respectively. Linearity of the continuous variables with respect to the logit of the dependent variable was assessed via the Box-Tidwell (1962) procedure. A Bonferroni correction was applied using all six terms in the model resulting in statistical significance being accepted when $p < .008$ (Tabachnick & Fidell, 2014). Based on this assessment, all continuous independent variables were found to be linearly related to the logit of the dependent variable. There were no standardized residuals. The logistic regression model was not statistically significant, $\chi^2(4) = 4.23$, p = .376 suggesting that user status and lineup condition do not predict lineup identification accuracy. In other words, being a cannabis user or receiving the target-present lineup condition did not affect the odds of an accurate lineup response (i.e., identifying the culprit when the culprit was present [true positive] or rejecting the lineup when the culprit was absent [true negative]). The model explained 13.4% (Nagelkerke R^2) of the variance in lineup identification accuracy and correctly classified 65.0% of cases. Sensitivity was 61.9%, specificity was 68.4%, positive predictive value was 68.4% and negative predictive value was 61.9%. Of the five predictor variables, none were statistically significant. Of note, user status may have reached statistical significance as a predictor of lineup identification accuracy with greater statistical power given the odds ratio (OR) of 0.26. See Table 7 for full results. See Tables 8 and 9 for cannabis users' and non-users' response distributions across lineup conditions and rates of lineup identification accuracy, respectively.

Table 7

Logistic Regression Predicting Likelihood of Accuracy based on User Status, Lineup Condition, Gender, and Years of Education

							95% CI for OR	
	B	SE	Wald	*df*	*p*	OR	Lower	Upper
User status	-1.36	0.76	3.18	1	.075	0.26	0.06	1.15
Lineup condition	0.04	0.68	< 0.01	1	.950	1.04	0.27	3.98
Gender	0.48	0.70	0.47	1	.491	1.62	0.41	6.33
Years of education	< -0.01	0.20	< 0.01	1	.992	1.00	0.67	1.49
Constant	0.62	3.33	0.04	1	.852	1.86		

Note. SE = standard error. OR = odds ratio. CI = confidence interval.

Table 8

Cannabis Users' and Non-Users' Response Distributions Across Lineup Conditions

	User Status		
	Users	Non-users	Total
Lineup Condition	*n* (%)	*n* (%)	*n* (%)
Target-present			
Correct identification*	4 (33.3)	6 (75.0)	10 (50.0)
Foil identification	2 (16.7)	1 (12.5)	3 (15.0)
Lineup rejection ("Not present")	6 (50.0)	1 (12.5)	7 (35.0)
Target-absent			
Foil identification	5 (55.6)	4 (36.4)	9 (45.0)
Lineup rejection ("Not present")*	4 (44.4)	7 (63.6)	11 (55.0)

Note. *Correct response.

Table 9

Lineup Identification Accuracy Rates Among Cannabis Users and Non-Users

	User Status		
	Users	Non-users	Total
Lineup Condition	*n* (%)	*n* (%)	*n* (%)
Target-present			
Accurate	4 (33.3)	6 (75.0)	10 (50.0)
Inaccurate	8 (66.7)	2 (25.5)	10 (50.0)
Target-absent			
Accurate	4 (44.4)	7 (63.6)	11 (55.0)
Inaccurate	5 (55.6)	4 (36.4)	9 (45.0)

Mediation Analysis

A PROCESS mediation analysis was run to examine whether ROCFT RT performance would mediate the relationship between user status and lineup identification accuracy. Preliminary assumption checking revealed that there were no outliers, which was determined by evaluating whether participants violated ($p < .001$) two or more distance markers (Mahalanobis distance, Cook's distance, and Leverage values). There was no multicollinearity ($r < .01$, $p = .993$). The data were not normally distributed, as assessed by visual inspection of histogram and as indicated by heteroscedasticity, as assessed by visual inspection of a plot of standardized residuals versus standardized predicted values. Results indicate that path *a* was not significant, $b = 0.03$, $SE = 3.89$, $p = .993$, 95% CI [-7.83, 7.90], $F(1, 38) < 0.01$, $p = .993$, $R^2 < .01$, suggesting that user status does not predict performance on the ROCFT RT. Similarly, user status ($b = -1.36$, $SE = 0.70$, $p = .053$, 95% CI [-2.74, 0.02]) and ROCFT RT ($b = -0.05$, $SE = 0.03$, $p = .101$, 95% CI [-0.11, 0.01]) did not predict lineup identification accuracy. Thus, ROCFT DR performance does not mediate the relationship between user status and lineup identification accuracy. Interestingly, however, user status and ROCFT RT performance together significantly predicted lineup identification accuracy, Nagelkerke $R^2 = .21$, $\chi^2(2) = 6.66$, $p = .036$. Further examination of variables in the equation suggests that being a cannabis user decreased the likelihood of an accurate lineup identification by about 74% (OR = 0.26) relative to non-users *and* for each unit increase in ROCFT RT performance, the likelihood of an accurate identification decreased by about 5% (OR = 0.95). Importantly, user status and ROCFT RT performance together remained significant predictors of lineup identification accuracy with removal of the two users who reported current other drug use, Nagelkerke $R^2 = .21$, $\chi^2(2) = 6.38$, $p = .041$, and with removal of the individual who did not abstain from cannabis for 24 hours prior to their appointment, Nagelkerke $R^2 = .20$, $\chi^2(2) = 6.16$, $p = .046$. However, when all three of these participants were removed from the analysis, user status and ROCFT RT performance were only marginally significant predictors of lineup identification accuracy, Nagelkerke $R^2 = .20$, $\chi^2(2) = 5.92$, $p = .052$.

An exploratory mediation analysis was also run to determine whether ROCFT DR (T-score) mediated the relationship between user status and lineup identification accuracy. Preliminary assumption checking revealed that there were no outliers, which was determined by evaluating whether participants violated ($p < .001$) two or more distance markers (Mahalanobis distance, Cook's distance, and Leverage values). There was no multicollinearity ($r = .06$ $p = .716$). The data were not normally distributed, as assessed by visual inspection of histogram and as indicated by heteroscedasticity, as assessed by visual inspection of a plot of standardized residuals versus standardized predicted values. Results indicate that path *a* was not significant, $F(1, 38) = 0.13$, $p = .716$, $R^2 < .01$, suggesting that user status does not predict performance on ROCFT DR. Similarly, user status and ROCFT DR do not predict lineup identification accuracy, Nagelkerke $R^2 = .18$, $\chi^2(2) = 5.93$, $p = .052$. Thus, ROCFT DR performance does not mediate the relationship between user status and lineup identification accuracy.

CHAPTER IV

DISCUSSION

The present study sought to evaluate the effects of chronic cannabis use on neuropsychological functioning and eyewitness memory. The first aim was to evaluate whether chronic cannabis users and non-users differed with regard to neuropsychological performance, specifically as it pertains to verbal and visual recognition. Next, this study sought to explore the effects of chronic cannabis use on eyewitness memory performance, specifically with regard to the number and accuracy of crime details recalled as well as lineup identification accuracy. Finally, this study sought to explore whether neuropsychological performance mediated the relationship between user status and lineup identification accuracy. Not only is there a dearth of literature examining the relationship between eyewitness memory and neuropsychological performance (e.g., Searcy, Bartlett, Memon, & Swanson, 2001; Roediger & Geraci, 2007), only two prior studies have examined eyewitness memory among cannabis users (Vredeveldt et al., 2018; Yuille et al., 1998), and this is the first study to examine both matters among a sample of *chronic* cannabis users who are not currently intoxicated.

Implications of Results

Validity test performance. Although not a primary area of investigation in the present study, it is notable that the author failed to reject the null hypothesis that chronic cannabis users and non-users would demonstrate similar PVT performance. This replicates findings from previous studies evaluating the cognitive effects of chronic cannabis use (Macher & Earleywine, 2012; Hirst et al., 2016). As mentioned previously, although the study is underpowered, RDS is the only PVT in which a potentially meaningful effect exists, as user status had a positive effect on CVLT-II FC performance and a negligible effect on TOMM performance. Thus, if users' had performed significantly worse than non-users' on neuropsychological measures, it is unlikely that such differences would be the product of suboptimal effort. Not only are PVTs useful for differentiating between genuine cognitive differences and suboptimal effort, the passing of PVTs subsequently aids in identifying whether such differences are clinically meaningful (Heilbronner et al., 2009). In other words, once it has been established that differences in neuropsychological performance are legitimate, it is important to evaluate whether scores from the experimental group, in this case cannabis users, fall in the clinically impaired range relative to baseline estimates of premorbid functioning. Otherwise, statistically significant differences have little clinical relevance with regard to the impact of cannabis on neuropsychological functioning.

Alternatively, failure to reject the null hypothesis may be due to the significant negative skew observed in the data, an expected phenomenon among PVTs given they are designed with the intention of being easily passable. Although this generally allows for adequate specificity, or the determination that suboptimal effort is *not present* when examinees *have* put forth adequate effort, it often compromises sensitivity, or the determination that suboptimal effort *is present* when examinees *have not* put forth adequate effort (Bigler, 2014; Larrabee, 2012). Thus, to prevent misclassification (i.e., false positives and false negatives), researchers are encouraged to examine the impact of subtle variations in effort on neuropsychological test scores rather than simply accepting the pass/fail dichotomies of PVTs as being suggestive of adequate effort (Green, 2007). For example, one study found that a continuous measure of effort mediated the relationship between frequency of cannabis use and memory performance, despite the fact that all participants passed PVTs (Hirst et al., 2016). This finding supports the notion that effort falls along a continuum, and the classification of effort into a pass/fail dichotomy may be misleading. Therefore, in addition to qualitatively evaluating the pass/fail dichotomies of PVTs employed in this study, the author also quantitatively examined group differences in PVT performance.

Neuropsychological performance among users and non-users. Given inconsistencies in the literature regarding the cognitive effects of chronic cannabis use, the author conducted an exploratory analysis to evaluate whether users' and non-users' differed significantly on verbal and visual recognition tasks. These two neuropsychological outcome measures were selected because of their relevance to the cognitive skills employed during either verbal recollections of an event or visual recollections during a lineup identification task. Again, the author failed to reject the null hypothesis, suggesting that users and non-users did not differ significantly on verbal and visual recognition tasks, duplicating findings from previous studies (e.g., Gruber et al., 2012; Macher & Earleywine, 2012). Although greater statistical power is necessary, it is worth noting that user status had a very small effect on verbal and visual recognition performance, suggesting that even if significant group differences are observed in a larger sample, such differences would be negligible. As a result, these preliminary findings have potentially important implications with regard to the effects of chronic cannabis use on cognition. Because the literature is somewhat equivocal regarding this matter (Schreiner & Dunn, 2012), additional exploratory analyses in this sample may help us to better understand the specific conditions in which chronic cannabis use may or may not have a significant effect on cognition. For example, one study found that cannabis users demonstrated poorer performance on measures of executive functioning relative to non-using controls; however, when controlling for frequency and severity of cannabis use, group differences were attributed to age of cannabis-use onset (Gruber et al., 2012). Moreover, if the finding that cannabis users and non-users demonstrate similar neuropsychological performance persists with greater power, cannabis may gain further traction as an accepted form of treatment for those medical conditions in which it has shown promise.

Eyewitness performance among users and non-users. Based on previous research, the author also hypothesized that chronic cannabis users would provide significantly fewer details of a simulated crime video relative to non-users, though the accuracy of details would not differ. The author failed to reject the null hypothesis that cannabis users and non-users would demonstrate similar eyewitness recall on the combined dependent variable, suggesting that the two groups did not differ significantly with regard to eyewitness performance. Again, despite the need for greater statistical power, the effect of cannabis on number and accuracy of details recalled was minimal. As a result, statistically significant differences in a larger sample would be inconsequential. It is interesting that results from the present study differ from those of Yuille and colleagues (1998), who found that cannabis-intoxicated participants recalled significantly fewer details relative to placebo immediately following a staged event, whereas accuracy did not differ between groups. Accuracy in the present study was calculated using Yuille et al.'s (1998) method (total number of accurate details divided by the total number of accurate and inaccurate details recalled). The discrepancy between findings from the present study and that of Yuille et al.'s

(1998) may be related to their samples' intoxication status. In other words, number of details recalled may be more vulnerable to the acute effects of cannabis intoxication. Results from the present study cannot be directly compared to Vredeveldt and colleagues' (2018) findings, as they examined correct and incorrect recall separately; however, Vredeveldt et al. (2018) found that cannabis-intoxicated participants recalled significantly fewer accurate details relative to sober participants, whereas the number of inaccurate details did not differ between groups. Broadly speaking, if chronic cannabis users and non-users demonstrate similar levels of accuracy with greater levels of power, judges may have increased confidence when deciding whether to admit cannabis users' testimony into trial. Additionally, in the event that the defense attempts to challenge the credibility of a cannabis-user eyewitness, experts can reassure the jury that the effect of cannabis user-status on eyewitness testimony is negligible, which may aid jurors in rendering a verdict. Ultimately, the finding that cannabis users and non-users are similar with regard to eyewitness accuracy may prevent potentially useful testimony from being discounted solely on the basis of user status.

The author further examined whether user status and lineup condition were significant predictors of lineup identification accuracy. Again, although results failed to reject the null hypothesis that there is no relationship between user status or lineup condition and lineup identification accuracy, greater power is necessary to maintain confidence in this finding. Of note, user status may reach statistical significance as a predictor of lineup identification accuracy in a larger sample given the large OR, which suggests that being a cannabis user decreased the likelihood of an accurate lineup identification by about 74% (p = .075). Similar to the implications noted above, this information has the potential to aid judges and jurors in their decision-making as it relates to the admission of an identification into trial or the rendering of a verdict. However, a larger sample is needed to replicate supplementary findings from Vredeveldt and colleagues' (2018) study, which found that acute cannabis intoxication did not increase rates of false positive errors or decrease rates of true positives. A precise analysis of response distributions across target-present and absent conditions is particularly important not only for determining accuracy, but for determining whether cannabis users differ from non-users in the *types* of errors made. Such information is an essential component of legal decision-making considering that, in the real world, police officers may unknowingly construct a lineup containing an innocent suspect (i.e., target absent). As a result, information regarding rates of false positives or false negatives would further inform the degree of confidence judges and jurors may place on cannabis users' lineup identifications to prevent wrongful conviction or the release of a guilty suspect.

Neuropsychological performance as a mediator between user status and lineup identification accuracy. Given that a lineup identification task relies on visual recognition, the author hypothesized that ROCFT RT performance would mediate the relationship between user status and lineup identification accuracy. A mediation analysis using Hayes' (2017) PROCESS macro found that user status did not predict ROCFT RT performance and neither user status nor ROCFT RT performance predicted lineup identification accuracy, suggesting that the proposed mediation model was nonsignificant (i.e., ROCFT RT did not mediate the relationship between user status and lineup identification performance). Additionally, although user status and ROCFT RT performance did not significantly predict lineup identification accuracy on their own, the two together were significant predictors of accuracy. More specifically, being a user *and* increases in ROCFT RT T-scores decreased the odds of accuracy. This finding is somewhat counterintuitive, considering that one might expect increases in ROCFT RT T-scores to increase the odds of accuracy; however, in the context of user status, this was not the case. One explanation for this unexpected relationship could be that facial recognition and object recognition are actually two separate neural processes. More specifically, research has shown that the brain processes faces using a more holistic, or configural, approach relative to objects (Robbins & McKone, 2007; Tanaka & Farah, 1993; Young, Hellawell, & Hay, 1987). In other words, we tend to view faces as the integration of multiple regions rather than as separate, individual features (Robbins & McKone, 2007). Researchers have found that this process relies on the fusiform face area, which is thought to be specialized for facial processing (Rhodes, Byatt, Michie, & Puce, 2004), whereas non-face objects activate other regions of the ventral occipitotemporal cortex (Grill-Spector, Knouf, & Kanwisher, 2004). Evidence of spared facial recognition in the context of lesions producing deficits in object recognition provides further evidence for separate neural processes (Moscovitch, Winocur, & Behrmann, 1997; McCarthy & Warrington, 1986). Thus, among cannabis users, lineup accuracy may not necessarily depend on superior ROCFT RT (visual recognition) performance as one might expect; however, it remains unclear why ROCFT RT performance is negatively associated with lineup identification accuracy. Ultimately, given that the data violated several important assumptions of the analysis, this finding may actually be spurious and therefore would not merit interpretation.

Limitations of the Present Study

There were several limitations to the present study. First, the sample size was relatively small, which resulted in too little power to detect group differences if differences did, in fact, exist. Thus, the author cannot draw firm conclusions regarding the lack of statistically significant differences between users and non-users in this study. The author made efforts to address the issue of small sample size by modifying inclusion and exclusion criteria while maintaining adequate control over potential confounds, as too few individuals qualified using the stringent criteria initially proposed in this study. To begin, the author broadened the age range for participants from 40 to 50 years old, as several cannabis-use studies have included participants up to 55 years in age (Fontes et al., 2011a; Pope et al., 2003; Solowij et al., 2002). In addition, although cognitive decline may begin as early as the twenties and thirties, several studies indicate that performance is generally stable until the late fifties and sixties (Aartsen, Smits, van Tilburg, Knipscheer, & Deeg, 2002; Plassman et al., 1995; Rönnlund, Nyberg, Bäckman, & Nilsson 2005). The author also reduced the minimum number of days that cannabis-using participants must have used cannabis from four to two days per week. As mentioned previously, this criterion would still establish an appropriate group of participants with a history of "primarily" cannabis use in accordance with experts' recommendations (Gonzalez et al., 2002). Although this requirement still exceeds that of several other studies examining the cognitive effects of chronic cannabis use (e.g., Lyons et al., 2004; Skosnik et al., 2008; Skosnik, Spatz-Glenn, & Park, 2001), it may have been insufficient to detect an effect of chronic cannabis use on neuropsychological functioning and eyewitness memory if one exists. The author also removed the requirement that non-users must have used cannabis at least once and no more than five times. Instead, individuals qualified as non-user controls if they had *never* used cannabis or had a history of cannabis use limited to a maximum of 30 lifetime uses. Finally, the author increased the number of times individuals were permitted to have used other drugs from 5 to 50 lifetime uses per class of drug. This change was intended to improve the external validity of study findings, as one study of witness intoxication rates found that, second to alcohol (58.6%), witnesses were most commonly suspected to be under the influence of multiple substances (24%; Evans et al., 2009). In addition, in a study analyzing the characteristics of cannabis users, those cannabis users classified as ineligible (48.6%) for a larger parent study were significantly more likely to report a history of other substance use relative to eligible cannabis-using respondents (20.3%; Rosen, Sodos, Hirst, Vaughn, & Lorkiewicz, 2018). Because ineligible cannabis users comprised the majority of the sample, they were thought to be more representative of cannabis users in the general community. Thus, restricting the sample of the present study to cannabis users with very minimal other drug use would limit the generalizability of study findings to more typical cannabis users. Unfortunately, despite these changes, recruitment still proved to be challenging, thus limiting the present sample.

Although the author adjusted inclusionary criteria in an effort to improve the generalizability of study findings, several criteria remain to restrict the external validity of the results reported herein. For example, findings from the present study may not translate to cannabis users with comorbid psychiatric concerns, problematic alcohol use, and/or medical or neurological conditions as well as those currently using psychiatric medications or who have sustained a head injury in the last six months. This is particularly notable given that chronic cannabis users from the region sampled are more likely to have a history of psychiatric conditions, to have used psychiatric medication, and to have engaged in a higher frequency of alcohol use (Rosen et al., 2018). However, because the present study reflects an understudied area of the literature, it was necessary to control for confounding factors that may obscure our ability to evaluate the effects of chronic cannabis use on neuropsychological functioning and eyewitness memory (Gonzalez et al., 2002; Temple, Brown, & Hine, 2010).

Another limitation pertains to the use of an online self-report survey to screen individuals for eligibility. As the study progressed, the author noticed that individuals completed the survey multiple times in what appeared to be an attempt to qualify for participation. For example, one person filled out the survey on five separate occasions. In one instance, this individual qualified to participate, but revealed on the day of their appointment that they were 60 years old, not 40 years old as specified in their survey response. Although it is possible that surveys were completed multiple times because of genuine changes (e.g., with regard to substance use patterns or psychiatric history), the aforementioned example suggests that individuals may have intentionally engaged in dishonest responding. Self-report surveys are also problematic given the probability of error resulting from difficulty understanding survey questions, difficulty recalling accurate information, and social pressure (Johnson & Fendrich, 2005). There is at least some evidence of the former, particularly with regard to estimations of grams of cannabis used per day across various methods of consumption. For example, one individual reported consuming 80 grams of cannabis per day in the form of edibles, which is highly questionable. Instead, the individual likely estimated the weight of the edible as a whole rather than the amount of cannabis infused into the product, despite prompts within the question encouraging respondents to report their estimates in grams of cannabis. It is also possible that providing estimates with such precision is problematic for users who do not purchase their products from a dispensary, where potency and grams of cannabis content are provided on the product itself. More accurate estimates of substance use patterns may be possible through the use of a standardized method, such as the timeline followback method (TLFB), an interview-based assessment that helps individuals retrospectively estimate substance use patterns, particularly alcohol and tobacco, through the use of a calendar (Fals-Stewart, O'Farrell, Freitas, McFarlin, & Rutigliano, 2000; Sobell, Sobell, Klajner, Pavan & Basian, 1986). Unfortunately, this method does not translate well to the evaluation of cannabis-use characteristics given the various methods for cannabis consumption, potency differences, and inhalation patterns (Gray, Watson, & Christie, 2009).

Additionally, at the time of participation, the author asked participants to estimate their length of abstinence from cannabis. This variable may have also been subject to the pitfalls of self-report.

Unfortunately, there is little utility to the collection of serum and urine markers to estimate last cannabis use given the long half-life of cannabis (Mariani, Brooks, Haney, & Levin, 2011). In addition, although the author asked participants to abstain from all substance use, including cannabis, at least 24 hours prior to their scheduled appointment, there was one instance in which a participant did not follow those instructions. Thus, it is possible that this individual was still experiencing the acute effects of cannabis. This point is illustrated in the finding that, when data from this individual were removed from analyses, along with two others who reported current other drug use, user status and ROCFT RT performance were no longer significant predictors of lineup identification accuracy.

Concern is also raised with regard to the use of a computer for collecting participants' event recollections and lineup identifications. In the real world, it is highly unlikely that investigators would place a witness at a computer and leave them to their own devices, particularly with regard to event recollections; however, computer technology does exist for lineup identification administration (MacLin, Zimmerman, & Malpass, 2005), with 39.2% of law enforcement agencies having employed computerized lineups since 1999 (PERF & NIJ, 2013). On the other hand, witness statements may be recorded on audio or video tape, by a stenographer, or by the investigators themselves (TWGEE, 2003). In these instances, the investigator is likely engaging the witness in a dynamic questioning process to facilitate the witness's memory for the event in question, thereby extracting a greater number of details. Given that an interviewer's line of questioning likely varies as a function of the details offered by the witness, the author felt this method to be too unstandardized for the purposes of the present study and therefore administered a standardized set of questions, a method that is not uncommon in eyewitness research (e.g., Hagsand et al., 2013a; Wang, Paterson & Kemp, 2013; Vredeveldt et al., 2018).

Finally, the small sample employed in this study limited the distribution of individuals among certain groups, thereby restricting analyses. For example, the author collapsed racial groups into those who self-identified as White and those who self-identified as another racial group, as several racial groups were comprised of very few individuals. With ongoing data collection, it is hoped that the author can achieve an even distribution of racial groups to better understand the role of race with regard to neuropsychological performance and eyewitness memory among cannabis users, particularly with regard to own-race bias and lineup identification performance. Similarly, although there was an even distribution of participants across lineup conditions in general (i.e., 20 participants in both the target-present and absent condition), the distribution of users and non-users within each condition was uneven (i.e., 12 users and 8 non-users in the target-present condition and 9 users and 11 non-users in the target absent condition). As a result, there were not enough individuals within each response category (i.e., true positive, true negative, false positive, false negative) to evaluate whether user status had an effect on specific types of accurate and inaccurate responses (e.g., whether cannabis use resulted in a higher rate of false positives). This information could potentially serve as an indicator of lineup identification accuracy among cannabis users in the real world.

Future Directions

Due to the low power observed in the present study, future studies should examine eyewitness performance among larger samples of chronic cannabis users and non-users. It is hoped that increased power will enable the author to have greater confidence that chronic cannabis users and non-users are similar with regard to neuropsychological and eyewitness performance. Persisting small effects in larger samples would provide further support that groups are similar. As mentioned previously, information regarding differences in neuropsychological functioning would further our understanding of the cognitive sequelae of chronic cannabis use, potentially informing medical decision-making. For example, if the cognitive effects of chronic cannabis use are inconsequential, such information may aid patients in deciding whether they might pursue this as an intervention. Alternatively, if reduced neuropsychological functioning is a side effect of chronic cannabis use, then patients should be provided this information in discussions pertaining to this form of treatment. Information regarding differences in eyewitness accuracy may also inform decision-making, though as it pertains to judges' and jurors' determination of admissibility or rendering of a verdict, respectively. In addition to the aforementioned, greater power may enable us to examine participants' performance on other neuropsychological measures and to evaluate response distributions across target-present and absent conditions. Information regarding the types of errors chronic cannabis users may make in target present (i.e., false positive or false negative) or target absent (i.e., false positive) conditions is needed to determine the likelihood of such errors in the real world.

Given the dearth of research evaluating eyewitness memory among cannabis users, there are a number of other fruitful avenues demanding attention for future research. For example, the control group in the present study was comprised of those who had *never* used cannabis as well as those who had a limited history of cannabis use (ranging from never having used to 10 lifetime uses). Thus, it would be beneficial to examine eyewitness accuracy among a control group solely comprised of those who have never used cannabis as well as two experimental groups, one comprised of light cannabis users and the other of heavy cannabis users, to further examine the conditions in which cannabis users are accurate or inaccurate eyewitnesses. Of note, the literature would also benefit from an established definition of "chronic" or "heavy" cannabis use given there is no consensus as to how researchers define such users currently (Temple et al., 2010). Similarly, an examination of eyewitness performance among early (i.e., prior to age 18) and late onset (i.e., after age 18) cannabis users is warranted, as several researchers have attributed neuropsychological differences between users and non-users to earlier age of onset (Gruber et al., 2012; Fontes et al., 2011b; Pope et al., 2003). Determining whether this finding applies to eyewitness accuracy would further inform real-world decision-making.

Additionally, an examination of cannabis users' eyewitness performance in the context of varying retention intervals will improve the generalizability of study findings. As mentioned previously, the retention interval, or the length of time in between the witnessing of an event and the provision of a statement or lineup identification, is generally unpredictable in the real world and may span several days, months, or even years (Read & Connolly, 2007). In contrast, the present study employed a ~5-minute retention interval following the video event during which participants were given the TMT. After this brief interval, participants completed the free and cued recall tasks, immediately followed by the lineup identification task. Although this presents challenges with regard to external validity, this design was chosen because it allows for greater experimental control, whereas a retention interval spanning several days or longer may result in a number of confounding factors that may obscure our ability to delineate the effects of cannabis on eyewitness accuracy (e.g., additional and varied cannabis use across participants during the interval, uncontrolled rehearsal, or distressing life events). Despite the inherent difficulties associated with delayed retention intervals, future research should explore changes in eyewitness accuracy among cannabis users across greater lengths of time for enhanced ecological validity.

While examining varying retention intervals, researchers might also explore the effects of encoding specificity, or state-dependent retrieval, on cannabis users' eyewitness performance. Encoding specificity maintains that memory is superior when an individual's state of recall parallels the state in which encoding initially took place (Thomson & Tulving, 1970; Tulving & &Thomson, 1973). To investigate this phenomenon, researchers may implement a study design similar to the design employed in Schreiber Compo and colleagues' (2016) evaluation of state-dependent recall in alcohol-intoxicated eyewitnesses. More specifically, cannabis users may be randomly assigned to receive either a cannabis cigarette, a placebo cigarette, or no cigarette prior to witnessing an event. Participants may then be asked to recall the event immediately or to recall the event after a specified retention interval, during which the recollection will take place in either the same or different state. Findings have the potential to demonstrate whether cannabis users should be interviewed immediately following an event while intoxicated or after a delay while sober.

It is also worth exploring whether variations in event medium (e.g., simulated video versus live staged event) and event content (e.g., degree of emotional valence) impact cannabis users' eyewitness accuracy. Although the video-event method is popular in eyewitness research given the ease of administration, consistency across participants (i.e., internal validity), and evidence of similar rates of accuracy relative to live staged events (Pozzulo et al., 2008), it is unclear whether the latter holds true for cannabis users. This calls into question the ecological validity of video-event research in this population. For example, discrepant findings pertaining to accuracy and confidence in Yuille et al.'s (1998) and Vredeveldt et al.'s (2018) studies may be related to the event medium employed (live staged event versus simulated video); however, it should be noted that direct comparisons between the two are limited due to differing analyses and operationalization of outcome variables, among other reasons. Ultimately, additional research examining the effects of simulated videos and live staged events on cannabis users' eyewitness accuracy will inform the degree of confidence we place in findings derived from video-event research with this population. Researchers should also manipulate the emotional valence of the event employed to evaluate the impact of stress and arousal levels on cannabis users' subsequent recollections (Pozzulo et al., 2008; Fawcett et al., 2013). This area of research may be particularly interesting given the effect of acute and chronic cannabis use on activity in the amygdala and anterior cingulate (Gruber et al., 2009; Rabinak et al., 2012), two regions of the brain involved in emotion regulation (Blumenfeld, 2010). Volumetric reductions of the amygdala are also relatively consistent among chronic cannabis users (Lorenzetti et al., 2015; Schacht et al., 2012). Ultimately, these neural alterations may be associated with reductions in stress reactivity among chronic cannabis users (Cuttler et al., 2017), resulting in superior eyewitness memory for stressful events relative to non-using controls.

Research investigating the effects of lineup administration procedures on cannabis users' eyewitness accuracy may also be of benefit, particularly given the unstandardized nature of lineup administration procedures across states and jurisdictions (Fitzgerald, Price, & Valentine, 2018; PERF & NIJ, 2013; Rodriguez & Berry, 2013). For example, 69% of law enforcement agencies administer photo lineups in a single-blind manner (PERF & NIJ, 2013), despite strong recommendations that a double-blind procedure be used to reduce the likelihood of expectancy effects (Rodriguez & Berry, 2013; Wells et al., 2012). Although the author's use of a single-blind lineup administration procedure in the present study reflects current practices, research comparing both double-blind and single-blind viewing conditions among cannabis users is recommended to evaluate their effects on accuracy, particularly with regard to expectancy effects. In fact, chronic cannabis users may be more susceptible to expectancy effects given that cannabis may reduce the impact of socially threatening stimuli and increase feelings of connectedness (Miller, Bershad, & de Wit, 2015). Not only will this inform best practices when confronted with cannabis-user eyewitnesses in the real world, this information will then enable judges and jurors to evaluate the validity of cannabis users' lineup identifications in the context of the method employed. In addition to evaluating single-blind and double-blind procedures as it pertains to the administration of the lineup itself, there is also a unique opportunity to evaluate whether examiner blindness of cannabis user status impacts lineup identification performance. Such information will further inform blind procedures used among law enforcement agencies. However, researchers may find an effect of examiner expectancies on lineup identification even among those kept blind to user status (Sodos et al., 2018). In this case, such knowledge will encourage caution when gauging the validity of a cannabis-user identification in the real world.

All studies investigating eyewitness memory among cannabis users to date, including the present study, have utilized a simultaneous lineup design, another reflection of current practice in law enforcement (NIJ, 2018). However, researchers encourage the use of sequential lineups in the real world given they enhance witnesses' degree of conservativeness, thereby reducing false identifications (Smalarz & Wells, 2012). Determining whether sequential lineups result in a similar degree of conservativeness among cannabis users may ultimately lead to recommendations regarding best lineup identification practices when confronted with a cannabis-user eyewitness. Importantly, cannabis users may benefit from the sequential lineup format given their susceptibility to memory distortions (Riba et al., 2015), which may increase false positive identifications when presented with a simultaneous lineup. As a result, researchers should evaluate cannabis users' response distributions among simultaneous and sequential lineups presented in both target-present and absent formats to determine which method enhances correct identifications and reduces false positives in this population.

In addition to carefully examining response distributions across lineup formats, it may be beneficial to evaluate differences in free and cued eyewitness recall separately. Doing so may help us to better understand the circumstances in which cannabis users have greater rates of accuracy. For example, if cannabis users perform better under cued recall conditions, law enforcement officers may wish to place more emphasis on cued recall testimony when investigating a crime, so long as the questions employed are not leading. Similarly, although some researchers have examined correct and incorrect details separately (e.g., Vredeveldt et al., 2018), it could be argued that this approach is less externally valid, as it fails to inform us of the quality of the testimony as a whole. For example, to what degree are correct details useful if there are an equal number of incorrect details? This is particularly problematic in the real world, as law enforcement officers are unaware of which details are accurate. Therefore, in addition to examining correct and incorrect details separately, calculating accuracy as the percentage of correct details of total details recalled (correct and incorrect), as done in the present study, would be advantageous.

Exploring variables with the potential to postdict cannabis users' eyewitness accuracy is another worthwhile area of investigation given the utility of this information in the real world. Two variables commonly researched for their postdiction potential include lineup identification response latency and decisional confidence. Examining whether response latency and confidence serve as markers of accuracy among cannabis users is more relevant now than in prior years given the Deputy Attorney General's recent issuance of department-wide eyewitness identification procedures, which requests that officers document both elements as they pertain to an identification (DOJ & Office of the Deputy Attorney General, 2017). Of note, the TWGEE's (2003) *Trainer's Manual for Law Enforcement* already asks that officers obtain a statement of certainty following a lineup identification; however, it does not ask that officers obtain a measure of response latency. Thus, with the issuance of the aforementioned memorandum, an examination of response latency certainly warrants further attention. Measures of speed may be used on their own (Brewer et al., 2006) or in combination with confidence levels (Sauerland & Sporer, 2009) to postdict the accuracy of cannabis users' lineup identifications. Moreover, although there is ongoing debate regarding the use of witness certainty as a measure of accuracy, researchers continue to advocate for this variable's potential as a meaningful postdictor (Wixted & Wells, 2017).

Summary

The present study aimed to investigate the effects of chronic cannabis use on eyewitness memory and neuropsychological functioning and sought to identify whether neuropsychological performance mediated the relationship between cannabis user status and eyewitness memory. The analyses reported herein failed to reject null hypotheses, suggesting that chronic cannabis users and non-users did not differ significantly with regard to neuropsychological performance or eyewitness performance. Although firm conclusions cannot be made regarding the equivalence of groups due to insufficient power, the small effects observed suggest that significant differences in a larger sample are unlikely to be clinically important. As a result, findings from the present study contribute meaningfully to the literature, irrespective of insufficient power. In addition, user status and lineup condition did not predict lineup identification accuracy; however, the strong association between user status and lineup identification accuracy suggests that user status may be a significant predictor of accuracy in a larger sample. Finally, ROCFT RT performance did not mediate the relationship between user status and lineup identification accuracy. Despite the low power observed, one interesting finding did emerge as a product of mediation analyses in which cannabis user status and ROCFT RT performance together predicted lineup identification accuracy, though not in the direction that might be expected (i.e., increases in ROCFT RT T-score decreased the odds of accuracy). Though possibly spurious, this finding motivates additional investigations into predictors of lineup identification accuracy among cannabis users as well as potential mediating factors of user status and lineup identification accuracy. The present study demonstrates only a fraction of the many possible areas for exploration within the realm of eyewitness memory as it pertains to cannabis users.

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APPENDIX A

IRB LETTER OF APPROVAL

INSTITUTIONAL REVIEW BOARD

Assurance Number: FWA00010885

July 08, 2017

Alexis Rosen
1791 Arastradero Rd
Palo Alto, CA 94304

FULL APPROVAL: 17-022-H Eyewitness memory and neuropsychological functioning in chronic cannabis users

Dear Ms. Rosen:

You have requested REGULAR review of the above-entitled protocol by the PAU IRB. You have provided necessary documentation including certificates of completion of human subjects research training. The PAU IRB has reviewed and approved this application to involve humans as research participants.

Approval Date: July 08, 2017

Approval Period: 12 months

Expiration Date: July 07, 2018
If the project is to continue, it must be renewed by the expiration date.

Modifications: Any changes to the protocol must be approved, in advance, by the IRB prior to being implemented.

Please print and retain this letter for your files. Sincerely,

Lisa Brown, PhD
Professor and Co-Chair, PAU IRB

1791 ARASTRADERO ROAD • PALO ALTO, CA • 94304
PHONE: 650-433-3827 • FAX: 650-433-3888

APPENDIX B

INFORMED CONSENT TO PARTICIPATE IN RESEARCH STUDY

PALO ALTO UNIVERSITY
Engaging Minds, Improving Lives

A. PURPOSE AND BACKGROUND
Alexis Rosen M.S., a graduate student at Palo Alto University, is working with Dr. Rayna Hirst, a faculty member at Palo Alto University, and research assistants in conducting a study to further our understanding about the effects of cannabis use on our cognition, or thinking skills such as learning and memory.

You are being asked to participate in this study because you have identified yourself as an adult in the United States who is between 18 and 50 years of age.

B. PROCEDURES
If you agree to be in this study, the following will happen:

1. The information you provided during the online questionnaire will be assigned a participant ID number, and your test results today will be linked to this ID number.

2. You will be asked to complete a field sobriety test, which involves assessing your balance and coordination to ensure that you are not under the influence of any substance. Please be aware that if you do not pass this test, you will not be able to complete the experiment at this time, but will instead be asked to participate in this experiment at a later date. In addition, we will have you arrange transportation to get home safely.

3. You will be asked to volunteer for approximately 2 hours. During this time, we will assess your mood and your impression of events, and you will be given a variety of tests that are meant to measure cognitive abilities, such as learning and memory. Research designs often require that the full intent of the study not be explained prior to participation. Although we have described the general nature of the tasks that you will be asked to perform, we will explain more about the intent of the study after your participation.

4. You agree that you give up access to the results of each test.

C. RISKS/DISCOMFORTS
1. A potential risk associated with participation in this study is the experience of psychological distress associated with answering questions regarding your mood, including thoughts of suicide.

Should you experience discomfort and wish to discontinue the mood questionnaires, or wish to stop for any other reason, you may discontinue at any time you wish to do so.

If the examiner sees that you are experiencing psychological distress while completing the mood questionnaires, the examiner may elect to discontinue the study to help you obtain appropriate clinical services. In addition, if your responses on the mood questionnaires indicate that you are experiencing extreme psychological distress or if you are at risk for suicide, the examiner will stop the study to contact a licensed clinical psychologist, who will conduct a follow-up interview with you by phone. They will then determine an appropriate course of action, which may involve your removal from the study. None of your data will be used in the research if the study is discontinued early.

You will also be given resources listed in Section G of this Consent Form to help respond to any potential psychological distress associated with depression or anxiety.

2. Another potential risk associated with participation in this study is test anxiety. Some of the tests we complete today may seem difficult or frustrating. Should you experience any discomfort during the study and wish to stop, or wish to stop for any other reason, you may discontinue at any time you wish to do so. Again, you will be given resources listed in Section G of this Consent Form to help respond to any potential distress.

3. Confidentiality: Participation in research may involve a loss of privacy. If this occurs, information regarding your substance use status or test results may become known. However, participant information will be handled as confidentially as possible. Special precautions will be taken to protect the identities of participants in the study and the confidentiality of all information provided. For example, your consent form will be separated from your online questionnaire and test data to ensure that your name will not be connected to such information. All records will be coded and kept in locked files so that only the study investigators have access to them. No individual identities will be used in any reports or publications resulting from this study. In addition, your consent form will be destroyed 3 years after study completion, and all electronic identifying information (link between name and ID number, email address supplied during online screening) will be erased as soon as participants' data has been collected, scored, and entered into a password protected database.

   As a reminder, if you decide not to participate or begin participation and withdraw consent, the de-identified data you provided during the initial online screener (e.g., cannabis, drug, and alcohol use history, psychiatric and medical health history) may still be analyzed as part of the research study and will be erased three years after study completion. However, data obtained during actual study participation (e.g., test data) will be destroyed if and when consent is withdrawn and will not be analyzed in any way.

4. If instances of soon-to-occur physical injury to self are discussed, they will need to be reported, as required by law. Although not directly asked, if instances of abuse (including neglect and/or exploitation) or soon-to-occur physical injury of another person (including children and or

vulnerable adults) are discovered, they will also need to be reported, as required by law. In addition, although unlikely, your information may require disclosure under a court-ordered release of information.

D. BENEFITS

There are no direct benefits to participating in this study. As a participant, you will contribute to the scientific progress of the field of psychology and to society.

E. PAYMENT

You will receive a $50 American Express gift card at the conclusion of your participation. Full completion of the study is necessary for compensation. You will not receive compensation for partial completion of the study. There is no cost to participate in this study.

F. QUESTIONS

If you have questions about the study, you may call Dr. Rayna Hirst at (650) 417-2025 or at rhirst@paloaltou.edu, or email Alexis Rosen at arosen@paloaltou.edu.

Questions about your rights as a participant in this study may be addressed to the IRB Chairperson:

Chair of IRB
Palo Alto University
1791 Arastradero Road
Palo Alto, California 94304-1337
Phone: (650) 433-3870

G. REFERRAL SOURCES

- If you are in immediate danger of harming yourself, or are having a psychiatric emergency, please call 911 immediately or go to your nearest emergency room.
- National Suicide Prevention Lifeline: 24 hrs/7 days: 1-800-273-8255; www.suicidepreventionlifeline.org
- Suicide Awareness Voices of Education: www.save.org
- Mental Health America at www.nmha.org
- For help with substance use issues:
    - **Marijuana Anonymous:** www.ma-sf.org
- **Local Resources:**
    - Mental Health Association of Santa Clara County
      www.sccgov.org/sites/mhd/Services/CallCenter/Pages/default.aspx
    - Mental Health Association of Alameda County
      www.mhaac.org/mental-health-resources.html
    - **Santa Clara County Behavioral Health Services**
      https://www.sccgov.org/sites/bhd/Pages/home.aspx
      Suicide and Crisis Hotline 24/7: 1 (855) 278-4204
    - **San Francisco Suicide Prevention**

http://www.sfsuicide.org/
24 Hour Crisis Line: (415) 781-0500

- **GENERAL SERVICES:**
  - **Central Wellness & Benefits Center**
    The Center provides basic behavioral health, crisis intervention, and benefit enrollment services to all clients. www.sccgov.org/sites/mhd/Services/CWBC/Pages/default.aspx
    - 2221 Enborg Lane
      San Jose CA 95128
      (408) 885-6220
      Office: M-F 8am-5pm

  - **Community Solutions**
    Direct treatment in mental health and drug & alcohol prevention, outreach, domestic violence services, residential and support programs. All services are also provided in Spanish. www.sccgov.org/sites/mhd/Services/Pages/OutpatientSupportServices.aspx
    - 9015 Murray Ave., STE 100
      Morgan Hill, CA 95020
      (408) 842-7138

  - **Berkeley Mental Health Division, Adult Services Program**
    Crisis evaluation and intervention, case management, psychotherapy (individual, family, or group), psychiatric medication evaluation and maintenance for Berkeley and Albany residents or homeless in Berkeley or Albany. Sliding scale.
    www.ci.berkeley.ca.us/mentalhealth
    - 2640 MLK Jr. Way
      Berkeley 94704
      (510) 981-5290
      Office: M-F 8am-5pm

H. CONSENT
Please keep one copy of this consent form for your records and we will maintain a record of the signed copy of this consent form.

PARTICIPATION IN RESEARCH IS VOLUNTARY. You have the right to decline to participate or to withdraw at any point in this study without repercussions, but there are no alternatives to this consent form. If you decide to terminate your participation in this study, you should notify Dr. Rayna Hirst or Alexis Rosen at (650) 417-2025.

You may contact Dr. Rayna Hirst or Alexis Rosen at (650) 417-2025 three or more months after your testing session if you wish to learn more about the conclusions of this study.

If you wish to participate, you should print and sign your name. Also, remember to put your initials on every page of this form.

____
Participant's Signature

______________________________ __________
Participant's Name (Printed) Date

______________________________ __________
Person Obtaining Consent Date

Payment Received ____________ Initials

OPTIONAL:
By signing and dating below, I give permission for the study investigators and researchers to contact me for future studies.

____
Participant's Signature

APPENDIX C

EYEWITNESS RECALL TASKS

OPEN-ENDED FREE RECALL TASK

Please describe the event you just witnessed in as much detail as possible. Include characteristics of the event, details of the location in which it took place, a description of the perpetrator, other people in the vicinity, etc. If you are unsure of any details, **please do not guess**.

OPEN-ENDED CUED RECALL TASK

You will now respond to a series of prompts and questions. Please provide a response even if you already provided the information during your first recollection of the event. If you do not remember, enter “DR” for "don't remember." Include as many details as possible when providing answers, but **please do not guess**.

In what section of the airport did the event take place?

Which airlines were advertised in the surrounding area?

What was the approximate age of the perpetrator?

0 10 20 30 40 50 60 70 80 90 100

Age (years)

What was the approximate height of the perpetrator?

0 Feet

0 Inches

What was displayed on the television screen?

What was the gender of the perpetrator?

What was the ethnicity of the perpetrator?

What was the approximate weight of the perpetrator?

0 50 100 150 200 250 300 350 400 450 500

Weight (pounds)

Describe the color and length of the perpetrator’s hair.

What was the perpetrator wearing? Describe style and color if possible.

How many people were standing in line with the perpetrator?

0 5 10 15 20 25 30 35 40 45 50

Provide specific details of the perpetrator’s crime.

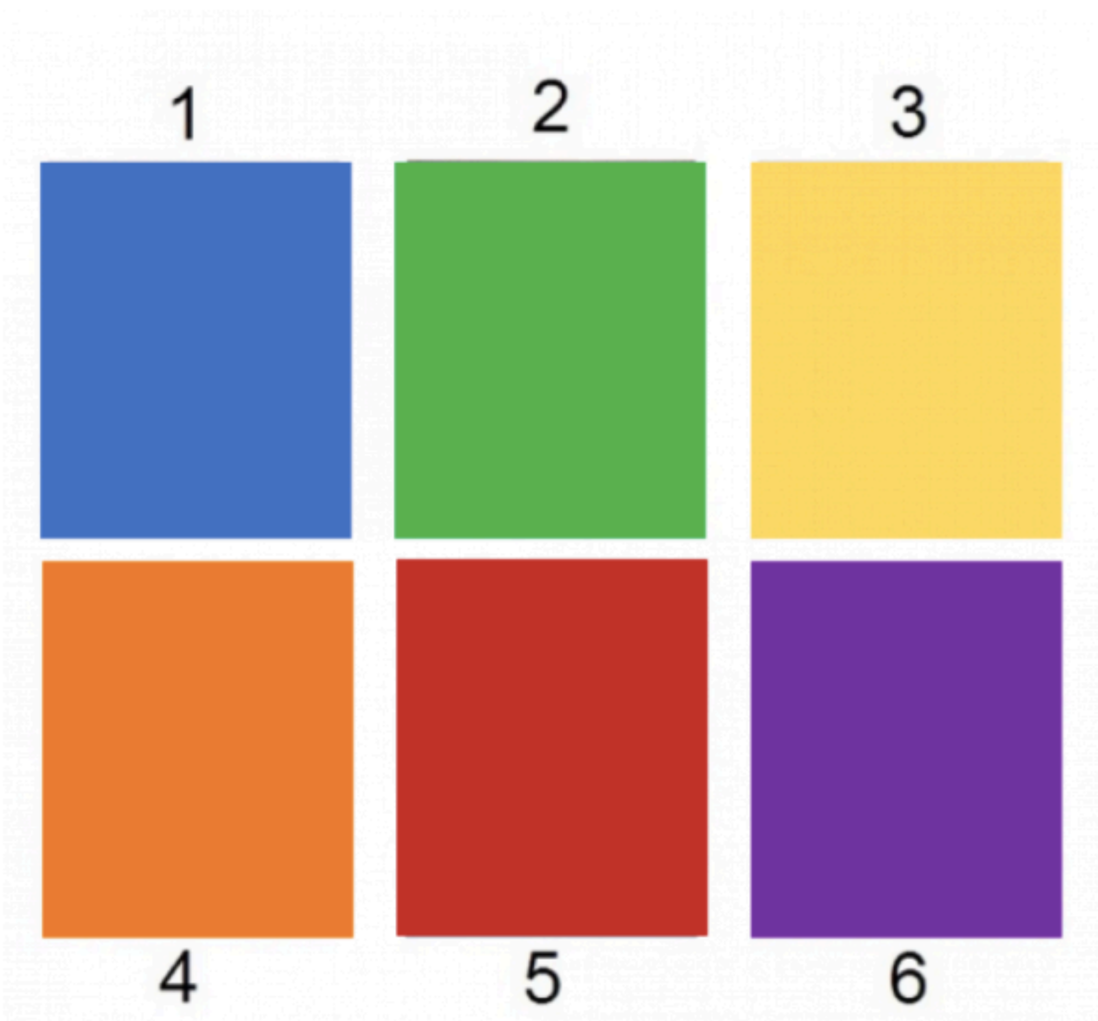
APPENDIX D

TARGET-PRESENT LINEUP

In a moment, you will be shown a photo lineup. You will be asked to decide whether or not you see the culprit's picture. The culprit's picture may or may not be present. Each face in the lineup will be numbered. You will select the number that matches the number of the person you believe to be the culprit. If you think that the culprit is not present, you will select the "not present" option.

For practice, please select the number that matches the color blue.

	1	2	3	4	5	6	Not Present
Your answer	○	○	○	○	○	○	○



>>

Now, please look at the lineup photos and decide whether or not you see the culprit's picture. The culprit's picture may or may not be present. If you see the culprit that was in the video, please select the number that matches the number of the person you believe to be the culprit. If you think that the culprit is not present, please select the "not present" option.

	1	2	3	4	5	6	Not Present
Your answer	○	○	○	○	○	○	○

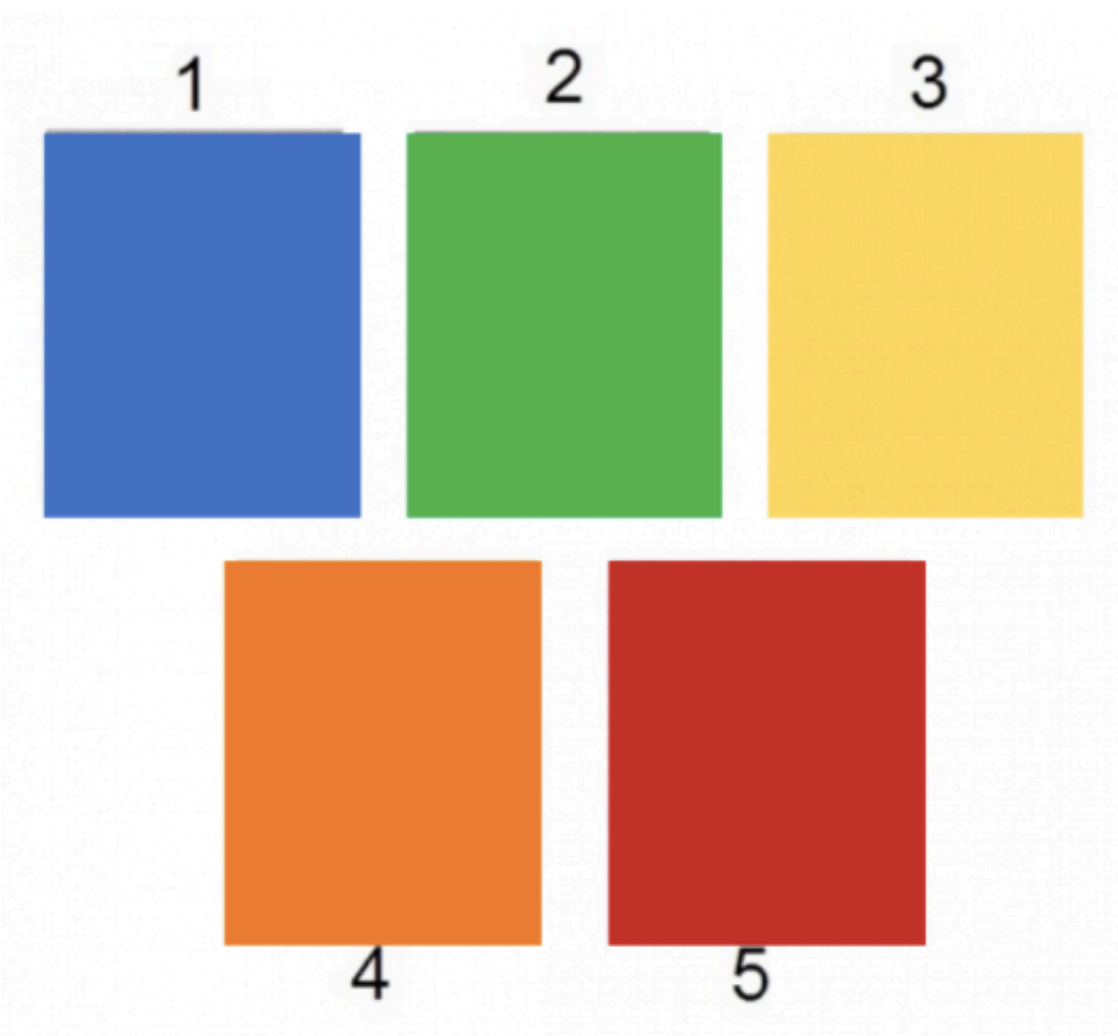
APPENDIX E

TARGET-ABSENT LINEUP

In a moment, you will be shown a photo lineup. You will be asked to decide whether or not you see the culprit's picture. The culprit's picture may or may not be present. Each face in the lineup will be numbered. You will select the number that matches the number of the person you believe to be the culprit. If you think that the culprit is not present, you will select the "not present" option.

For practice, please select the number that matches the color blue.

	1	2	3	4	5	Not Present
Your answer	○	○	○	○	○	○



>>

Now, please look at the lineup photos and decide whether or not you see the culprit's picture. The culprit's picture may or may not be present. If you see the culprit that was in the video, please select the number that matches the number of the person you believe to be the culprit. If you think that the culprit is not present, please select the "not present" option.

	1	2	3	4	5	Not Present
Your answer	○	○	○	○	○	○

APPENDIX F

CONFIDENCE RATING

On a scale from 0% to 100%, how confident are you that the photo you selected was the culprit?
If you did not select a photo, how confident are you that the culprit was not present in the lineup?

0% = not at all confident
50% = somewhat confident
100% = entirely confident

0 10 20 30 40 50 60 70 80 90 100

Level of confidence