Does Lying Require More or Less Working Memory and What Does it Mean for the Legal System?

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DEDICATION

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Introduction

Neuroscience and the Law

Recent decades have seen increasing awareness in both the neuroscience and legal fields of the potential for cross pollination between the fields. The term "neurolaw" was first coined in 1991 (Taylor, Harp, & Elliott, 1991) and the topic was featured on the cover of the New York Times Magazine in 1997 (Rosen, 2007), though its roots trace far longer (Shen, 2016). Since then it has grown into a staple in many academic institutions, led to multiple text books, and the creation of The MacArthur Foundation Research Network on Law and Neuroscience which has dedicated over $7.5 million to research at the intersection of law and neuroscience (Jones & Shen, 2012).

Neuroscience based evidence has also increasingly penetrated the courtroom. From quantitative EEG to diffusion tensor imaging, practitioners are increasingly leveraging neuroscience evidence to make their cases (Farahany, 2016; Jones & Sundby, 2015). While these efforts have met with mixed success, with many courts finding the evidence does not meet the Daubert standard of admissibility (Murphy, 2016; *US v. Semrau*, 2012), whether or not to admit neuroscience based evidence is a question judges are increasingly facing (Jones & Sundby, 2015). Many researchers, however, have questioned the ultimate utility of this case-by-case use given the group to individual (G2i) problem; while neuroscience research can tell us a lot about the traits of a group, it can be problematic to carry these inferences to any one individual on trial (Faigman, Monahan, & Slobogin, 2014).

On a broader scale, neuroscience has also reached beyond individual cases to influence broad legal policies. For example, the Supreme Court relied on brain science research that identified major distinguishing characteristics between juveniles and adults as a primary justification for its holdings that the death penalty, life without parole for non-homicide offenses, and mandatory life without parole for any crime were unconstitutional for juveniles (Haider, 2006; Maroney, 2011; *Roper v. Simmons*, 2005; *Graham v. Florida*, 2009; *Miller v. Alabama*, 2012). While yet to alter policy, additional research has laid the ground work to do so, such as studying the basis for third party punishment (Ginther et al., 2016). Other scholars argue that neuroscience will fundamentally shift our culpability based justice system as we learn that criminals are “victims of neural circumstances” and so retribution cannot justify punishment (Eagleman, 2011; J. Greene & Cohen, 2004). On the other end of the spectrum, some scholars argue that neuroscience is nothing but the “newest science on the block” and offers only modest contributions to legal policy and does not pose an existential threat to the “law’s concept of person and responsibility” (Morse, 2011).

While the potential for neuroscience to influence substantive legal policy has stolen the academic spotlight, its potential to inform procedural rules has been underappreciated. In many ways, however, using neuroscience to help design procedural rules has more promise in the short term to influence the justice system as it entirely avoids the G2i problem. Additionally, procedural rules can be just as important in the administration of justice as substantive rules. Increasingly, scholars have questioned the legal dichotomy between procedural and substantive rules and argued that procedural law is inherently substantive and that substantive law cannot exist separate and apart from the procedures that will be used to enforce it (Main, 2009). To try and fill this void, I have over the course of my doctoral program focused on developing and using electroencephalography (EEG) and behavioral experiments to directly assess the assumptions underlying legal procedural rules.

Neuroscience's impact on legal policy has been limited partially because of the lack of neuroscience experiments directly targeting a legal assumption, which would lessen the need to extrapolate from experimental results targeted at tangential questions. The Federal Rules of Evidence (FRE) govern all evidentiary decisions in federal courts and can have a profound impact on the outcome and fairness of cases and are one of the largest and most important sets of rules in the legal system. In my dissertation I will provide a brief overview of the FRE and its place in the legal system, introduce the Present Sense Impression (PSI) – one of the FRE, explain the PSI's underlying psychological assumptions, provide an overview of some of the current theories of lie generation, discuss the interplay between these theories and theories of working memory, and some of the main problems with behavioral paradigms used to study lying. I will then describe three sets of experiments in which we use behavioral paradigms and EEG measurements to directly assess the psychological assumptions underlying one of the FRE, the PSI. This dissertation serves as a case study for how neuroscience research targeted at specific legal questions can provide policy makers with better information when crafting procedural rules and hopefully result in a more just legal system.

The Federal Rules of Evidence

The FRE and Their Commitment to Accuracy, Efficiency, and Legitimacy

Before delving into how to test the rules of evidence, it is important to understand their background, goals, and importance to the legal system. The FRE were adopted in 1975 and govern all evidence decisions in federal courts (Weinstein & Berger, 2008). The FRE guides the admissibility of evidence at trial and determines what is permissible for the jury to consider in making its factual determinations. While the FRE was at least the third attempt to codify the rules of evidence and increase the consistency of evidentiary rulings, it was the first to be embraced by the states with at least forty-two states adopting rules premised on them (MacFarland, 2001, pp. 909–912; Weinstein & Berger, 2008). While the FRE's goals are multifaceted, their primary aim, apart from generally promoting the interest of justice, is to balance the often-competing interests of accuracy, legitimacy, and efficiency (Brown, 2011; Tyler & Sevier, 2014). As this section will illustrate, most rules can be categorized as promoting one of these three primary interests, often at the cost of one of the others. This section will go on to illustrate that these rules' success in promoting these interests often depend on the validity of underlying psychological assumptions.

Accuracy is perhaps the most important of the three specific aims with FRE 102 stating "These rules should be construed so as to administer every proceeding fairly, eliminate unjustifiable expense and delay, and promote the development of evidence law, to the end of ascertaining the truth and securing a just determination" (102 F.R.E.). FRE 102 makes clear that while efficiency and legitimacy are important, accuracy is the end goal.

While the theme of promoting accuracy runs throughout, specific rules particularly illustrate this aim. FRE 401, the gateway through which all evidence must pass, requires that all evidence be “relevant,” defined as having both “any tendency to make a fact more or less probable than it would be without the evidence” and “the fact is of consequence in determining the action” (401 F.R.E.). This rule illustrates an instance when accuracy and efficiency concerns are in harmony since limiting evidence based on relevancy also clearly promotes efficiency. The rule still, however, plays an essential role in promoting accuracy by preventing confounding and irrelevant evidence from reaching the jury.

Another example of a set of rules specifically targeting accuracy is the “best evidence rule,” comprising FRE 1001 – 1008, which requires the production of the original document if the moving party is seeking to prove its contents. This, unlike FRE 401, however, is an instance when accuracy and efficiency concerns are at odds. The structure of rules 1001 – 1008 is instructive of the relationship between these aims; rule 1002 lays out the general premise that the original document must be produced in the interest of accuracy, and rules 1003 – 1007 lay out exceptions to this general principle in the interests of efficiency (1001-1008 F.R.E.).

The text of FRE 102 also clearly establishes efficiency as a core goal of the evidentiary rules; “These rules should be construed so as to administer every proceeding fairly, eliminate unjustifiable expense and delay” (102 F.R.E.). We have already seen illustrations of efficiency’s influence in the structure of “the best evidence rule” and in the functioning of rule 401, but FRE 403 provides a more direct example. FRE 403 explicitly allows the exclusion of evidence, even if relevant, “if its probative value is substantially outweighed by a danger of one or more of the following: unfair prejudice, confusing the issues, misleading the jury, undue delay, wasting time, or needlessly presenting cumulative evidence.” The second part of this rule, “undue delay, wasting time, or needlessly presenting evidence,” speaks to the efficiency interest and allows the exclusion of relevant evidence if the efficiency interest substantially outweighs the evidence’s benefits to accuracy. Once again, we also see the value of accuracy enshrined within the same rule since evidence can also be excluded if there is a danger of misleading or confusing the jury.

Unlike the other two specific aims, there is no textual commitment in the rules to promote legitimacy. Legitimacy is similar to accuracy, but is more concerned with the public’s *belief* in the accuracy and fairness of the system, rather than its actual accuracy and fairness (Tyler & Sevier, 2014). Despite the lack of explicit textual commitment, this principal’s influence can be prominently seen in several rules. A prime example is FRE 606(b)(1), which bans jurors from testifying about any statements made during deliberation, the effects of any factor on deliberations, or any juror’s mental processes during deliberations (606(b)(1) F.R.E.). This rule is difficult to justify on accuracy grounds since from an accuracy perspective it would be vital to know about jurors consuming cocaine, alcohol, and marijuana in the jury room, as occurred in one prominent case in which the juror was not allowed to testify about the misconduct (*Tanner v. United States*, 1987). While this rule could be premised on efficiency grounds, in a Supreme Court decision to exclude evidence of jury misconduct the justices in the majority explicitly cited the need to preserve “the community's trust in a system that relies on the decisions of laypeople” as a core component of their decision (*Tanner v. United States*, 1987, pp. 120–121).

Another example of the influence of legitimacy is the general ban on the use of character evidence against a defendant established in FRE 404 (404 F.R.E.). Character evidence is evidence that goes towards a person's personality or character trait and cannot be used to show that a person, in a particular instance, acted in accordance with that trait (404 F.R.E.). The rule goes on to establish a variety of exceptions not grounded in efficiency and that assume that character evidence can be an accurate predictor of future acts, at least in some circumstances. For example, FRE 404(2)(B) allows the defendant to introduce character evidence pertaining to a relevant characteristic of the victim unless prohibited by FRE 412 (404 (2)B) F.R.E.; 412 F.R.E.). The California Supreme Court, in rejecting a proposed rule to expand the admissibility of character evidence stated "It subtly permits the trier of fact to reward the good man to punish the bad man because of their respective characters despite what the evidence in the case shows actually happened" (*Tentative Recommendation and a Study Relating to the Uniform Rules of Evidence (Art. VI. Extrinsic Policies Affecting Admissibility)*, 1964, p. 615). The primary concern is a perception that defendants will be condemned for their prior acts, rather than upon the evidence pertaining to the crime in question. Indeed, the entire idea of "undue prejudice," featured in rule FRE 403's balancing test, implies that factors other than accuracy can undermine the admissibility of evidence (403 F.R.E.).

This section illustrated the FRE's commitment to promoting and balancing accuracy, efficiency, and legitimacy. As we all know, however, goals are never enough. The next section illustrates how their success in achieving these aims is dependent on the validity of psychological assumptions underlying the rules about how people produce, process, and react to information.

The Psychological Assumptions Behind the Rules

The success of the rules in promoting the aims discussed in Part I.B(i) often depends on underlying psychological assumptions about how people think and process information. This section highlights some of the unspoken assumptions behind specific rules and how the efficacy of the rule in promoting its aim often depends on the validity of these assumptions. The close scrutiny of three rules will illustrate the frequent interdependence between the rule's assumptions and aims.

As discussed in Part I.B(i), FRE 403 has accuracy, efficiency, and legitimacy underpinnings and allows the exclusion of evidence if its probative value is substantially outweighed by the danger of "undue prejudice." The exclusion of evidence for being unduly prejudicial, however, assumes that jurors can be influenced by emotional impulses to the point that it overrides, or influences, their deliberative abilities. A prime example is the limits courts place on the admission of gruesome crime scene photos. While almost all courts admit crime scene photos, concerns over juror emotions unduly affecting their decision-making have led courts to ban photos if they are unnecessarily gruesome, revolting, or inflammatory (Dransfield, 2015).

Another rule that depends on a psychological assumption to promote its aims is FRE 609, which creates an exception to the ban against character evidence for impeachment of truthfulness with past felony convictions or crimes of deceit (609 F.R.E.). This rule is designed to promote accuracy, at a cost to the legitimacy interest behind the general ban because there is nothing about the exception which has lessened the risk that the jury will "punish the bad man because of their respective characters despite what the evidence in the case shows" (*Tentative*

Recommendation and a Study Relating to the Uniform Rules of Evidence (Art. VI. Extrinsic Policies Affecting Admissibility), 1964, p. 615). Yet, accuracy is only promoted if past deceitful behavior is an accurate predictor of future deceitful behavior. In other words, this rule depends on the assumption that a person's character trait for truthfulness is at least somewhat consistent across time. Otherwise, the cost to the legitimacy interest is incurred without any benefit for accuracy.

FRE 105 is the third rule that we will examine with an underlying psychological assumption. FRE 105 requires the judge to issue limiting instructions to the jury if admitted evidence is admissible for one purpose but inadmissible for a different purpose. This example illustrates that the balance is far more intricate than the previous two examples suggested. There are two possible motivations behind FRE 105, one grounded in efficiency and one grounded in accuracy. The rule may promote accuracy since issuing the instruction allows the jury to use the evidence for the permissible purpose, but not the impermissible purpose, thereby increasing the probability of an accurate result. The rule may promote efficiency since limiting instructions allow a degree of double dipping, by allowing the evidence to be simultaneously excluded and admitted without having to do a more costly procedure such as declaring a mistrial if the jury has already seen the evidence. This efficiency aim is promoted regardless of a juror's actual ability to use the evidence for one purpose and not the other. Yet, if jurors cannot maintain this mental division—as is likely the case (Lieberman & Arndt, 2000)—policy makers may not be fully weighing the cost to accuracy when deciding how to balance these competing interests. While the validity of the assumption is not essential to promoting the specific aim of the rule, it remains essential to obtaining the balance sought by the policy makers who drafted the rule.

The Implications of Inaccurate Assumptions and How to Test Them

The previous section illustrated the interdependent relationship between a rule's underlying psychological assumptions and its aims, and the importance of this relationship for maintaining the balance of the entire FRE framework. This section will discuss the possible implications if these psychological assumptions are false for each of the three specific aims of the FRE, and what these effects may mean for the overall goals of the justice system.

While the exact effect of an inaccurate underlying assumption will vary depending on the rule and can't be perfectly predicted, some effects on accuracy, legitimacy, and efficiency are generalizable. There are, for example, few, if any, instances in which an inaccurate assumption will promote the goal of accuracy. There are, however, instances when an inaccurate assumption will not negatively affect accuracy, or only slightly so. One example might be if gruesome photos do not unduly affect jurors' deliberative abilities. Since this rule errs on the side of excluding evidence, the only cost to accuracy is in the omission of any information that was only contained within the photo. This exclusion versus inclusion dichotomy and its effects on accuracy, however, cannot be broadly generalized. The effect on accuracy will depend on how vital the excluded evidence is to achieve an accurate outcome. If, for, example, a confession is excluded (for reasons other than a belief it is false), the accuracy cost could be very high. Overall, in most instances an inaccurate psychological assumption will decrease the accuracy of the justice system, though the degree of impact will depend on both the rule and to what degree the assumption is wrong.

The effects on legitimacy and efficiency are harder to generalize. The loss of legitimacy may actually depend on the public perception of the assumption's validity rather than its empirical validity. If, for example, deceitfulness is not a stable characteristic and past crimes of deceit have no predictive value for future deceit, FRE 609 has a negative effect on the accuracy of the system. Nonetheless, if people continue to *believe* that past deceitfulness is a reliable predictor of future deceit, Rule 609 would not negatively impact the system's legitimacy in the public's eye (Tyler & Sevier, 2014).

Similarly, as we have already seen with FRE 105 limiting instructions, a rule based on an inaccurate assumption can still promote efficiency. In many cases it may be that the efficiency interest is unaffected by the accuracy of the rule's underlying assumption. It does, however, change the balance between efficiency, accuracy, and legitimacy that the policy makers assumed in designing the rule. In addition to frustrating the balance of the individual rule, it may tilt the balance for the overall system with important distributional and justice implications.

Beyond the impact on the three specific aims of the FRE, rules premised on inaccurate psychological assumptions increase the odds of a fundamental miscarriage of justice. While balancing accuracy with efficiency may be a necessary evil, it has important distributional concerns. Generally speaking, the cost of inefficiencies is more likely to be economic and will be borne by the justice system and distributed across society. Inaccuracy concerns, on the other hand, are at least as likely to be borne by an individual party as the government and are more likely to involve interests beyond economics such as liberty. Basing rules off of inaccurate assumptions risks tilting the balance in such a way that we can justify grave inaccuracies in the name of efficiency gains, potentially with great costs to the overriding goal of the whole system, justice.

Despite these high stakes, it may be that these underlying psychological assumptions are simply untestable, and so policy makers are justified in making their best intuitive guesses about how people think. Until recently, this was unquestionably true for many of the assumptions. While the findings of behavioral and psychological experiments have been underappreciated in legal policy, they have their intrinsic limitations. Ultimately, no matter how sophisticated the experimental design, pure behavioral studies cannot tell us *how* a person is actually processing information. New techniques in neuroscience, however, are now making it possible to look at the brain activity of an awake human being conducting cognitive tasks. Given the dramatic role these psychological assumptions play in our legal system, it is advisable to at least investigate whether neuroscience can shed light on their validity.

The Hearsay Rules and Their Psychological Foundations

This section introduces the rules of evidence pertaining to hearsay. The hearsay rules have been among the most discussed—and criticized—evidentiary rules in the academic literature, and the labyrinth of intersecting rules often dominates law school evidence classes. Many of the exceptions to the general ban have clear psychological assumptions underlying them, making them ideal case studies for testing neuroscience's potential to influence procedure.

FRE 801 defines any out-of-court statement offered in evidence to prove the truth of the matter asserted as hearsay and declares it inadmissible (801 F.R.E.). The definition of the "truth of the matter asserted" is best illustrated by example. If an heir wanted to prove that the decedent was competent when he wrote his will, he could introduce a business contract the decedent drafted around the same time as the will, not to prove the contents and particulars of the substantive agreements detailed in the contract, but rather to prove—by way of the contract's existence and detail—that the decedent was competent during the time in question (Sevier, 2015). Note, however, that if the contract was offered to prove a *contested detail* of the obligations within the contract, it would be hearsay since it is an out-of-court statement (written by the decedent, offered by the heir) and is now being offered to "prove the truth of the matter asserted" (the contested detail). This rule promotes all three of the goals of the FRE: accuracy, legitimacy, and efficiency. The ban primarily promotes accuracy, as shown in the advisory committee's reasons for adopting the ban from the common law. The advisory committee decided to ban hearsay evidence because it lacks the three traditional safeguards of the witness being under oath, subject to cross-examination, and present for assessment of reliability by the jury (Art VIII F.R.E., advisory committee's notes; MacFarland, 2001, pp. 913–914). The lack of these safeguards jeopardizes the system's accuracy by increasing the risk of undetected errors in each of the four types of witness errors: perception, memory, narration, and deceit (Art VIII F.R.E., advisory committee's notes). The long and widespread acceptance of the hearsay ban also suggests a widespread belief in its efficacy and importance in promoting legitimacy (MacFarland, 2001, pp. 908–912; Tyler & Sevier, 2014).

FRE 801, however, clearly comes at a cost to efficiency; it can be very burdensome to always call the original declarant. The exceptions in FRE 803 and 804 are a concession to this tradeoff (803 F.R.E.; 804 F.R.E). The many exceptions encapsulated by FRE 803 and 804 tend to fall into one of three categories: when the traditional sources of inaccuracy are lessened, when concerns about the evidence's accuracy are less important, and when there is an overriding interest in efficiency. FRE 804, which lists exceptions to the general hearsay ban when the declarant is unavailable, best illustrates the nod to efficiency and practicality (804 F.R.E).

The best example of accuracy's influence on the exceptions is in the definition of hearsay itself. Under the hearsay definition established in FRE 801 statements "not offered for their truth" are not hearsay at all, such as our example of the contract introduced to prove competency, not a detail of the agreement (Sevier, 2015; 801 F.R.E). Other examples arise when the traditional sources of inaccuracy are lessened. FRE 803(3), for example, creates an exception for statements about "then-Existing Mental, Emotional, or Physical Condition" (803(5) F.R.E). This exception can be justified on the grounds that there is significantly less risk that individuals misperceive their own mental, emotional, or physical condition than an externally perceived event. FRE 803(5), creating an exception for recorded recollections, can be classified as an instance in which there is reduced concern for the chance of memory errors because the recollection was also recorded in a medium other than the individual's memory while it was still "fresh" in their mind (803(5) F.R.E). Similarly, FRE 803(4)'s exception for statements made for medical diagnoses can be justified as an instance in which there is a significantly reduced risk of deceit because an individual is less likely to lie when her health is at stake. The advisory committee explicitly acknowledges this basis citing a "guarantee of trustworthiness” for statements made for the purpose of diagnosis or treatment (803 F.R.E., advisory committee's notes).

Other examples include when the risk of deceit is thought to be lower not because of the speaker’s motivation, but because of assumptions regarding the declarant’s ability to lie. FRE 803(2), the “excited utterance” exception, creates an exception for statements “relating to a startling event or condition, made while the declarant was under the stress of excitement that it caused” (803(2) F.R.E.). The advisory committee notes explicitly state that the belief underlying the exception is the declarant’s reduced ability to lie, stating “the circumstances may produce a condition of excitement which temporarily stills the capacity of reflection and produces utterances free of conscious fabrication (803 F.R.E., advisory committee's notes).”

These examples illustrate how the hearsay rules and exceptions serve the overall purposes of the FRE by promoting accuracy, legitimacy, and efficiency, as well as ensuring that justice is served. The examples also illustrate how the exceptions to the hearsay rule tend to arise when the traditional risks of testimonial evidence are believed to be lessened, and that these beliefs are premised on psychological assumptions. The remainder of this paper focuses on one of these exceptions, the PSI, as a case study for the potential of neuroscience to contribute to the design of procedural rules.

The Present Sense Impression Exception and the Lack of Science Behind It

This section introduces the present sense impression exception through its text, historical development, and modern usage. It then delves into its underlying assumptions and the scientific literature relevant to assessing these assumptions’ validity.

The PSI was formally codified and adopted in 1974 as rule 803(1) of the FRE (MacFarland, 2001, p. 912). Rule 803(1) states "[a] statement describing or explaining an event or condition, made while or immediately after the declarant perceived it" (803(1) F.R.E.). Courts have interpreted this rule as having three requirements: (a) the statement must describe the event in question; (b) the declarant must have perceived the event in person; and (c) the event and the statement must have been "substantially contemporaneous" (Bourdeau, 1997, sec. 2a). For example, if Joe and Dave are driving in a car and, as a red car drives past, Dave states, "that car was really speeding, I would [not] be shocked if it gets in an accident." Joe would be able to testify under the PSI exception as to what Dave said, instead of Dave having to be hauled into court himself ("Example: Present Sense Impression," Legal information Institute).

The PSI traces its roots to the *res gestae* doctrine. *Res gestae* is Latin for "things done" and emerged in the English common law in the early 1800s as an exception to the hearsay ban when the hearsay statement and the event in question were so inextricably interwoven that one could not be understood without the other (Furman & England, 2009). This typically was defined as anything said reflexively to an event, without thought, and gradually expanded to cover evidence which today would be admissible under the PSI or excited utterance exceptions or when offering it only to prove that the words were spoken (Furman & England, 2009). James Thayer is credited with reviving the doctrine in the late 1800s and it was included in both the Model Code of Evidence in the 1940s and the 1953 Uniform Rules of Evidence before being codified in its present form in 1975 as rule 803(1) of the FRE (MacFarland, 2001, pp. 908–912). Despite frequent criticism (the ABA even opposed it's adoption) (MacFarland, 2001, p. 909), the rule has survived to the present day, and some version of the rule has been adopted in four-fifths of the states (MacFarland, 2001, p. 907).

When the PSI is invoked, the most contentious and most variable issue is the "substantially contemporaneous" requirement. A survey of published cases reveals evidence being admitted under the PSI with a temporal range between a few seconds and up to twenty-three minutes (*United States v. Blakey*, 1979, p. 785; *United States v. Portsmouth Paving Corp.*, p. 323; MacFarland, 2001, p. 920). *United States v. Blakey*, the case that admitted a statement uttered twenty-three minutes after the event, highlighted the subjectivity in the admission decision stating "There is no *per se* rule indicating what time interval is too long under Rule 803(1)" (*United States v. Blakey*, 1979, p. 785). Courts frequently recite this quote before embarking on the largely subjective decision of admitting or excluding the evidence (MacFarland, 2001, n. 66). This has bred variability in judicial application of the rule. While many courts accept evidence within the range established above, others have rejected PSI evidence within the very same range, with some courts rejecting statements near the center of that range, a ten-minute lag (*United States v. Hamilton*, 1996, p. 639). Much of the variability stems from the advisory committee note: "Exception (1) recognizes that in many, if not most, instances precise contemporaneity is not possible, and hence a slight lapse is allowable" (803 F.R.E., advisory committee's notes). The question that divides courts is how much time is a "slight lapse."

This variation in interpretation serves as a window into the underlying assumption behind the PSI exception. As mentioned, the advisory committee notes state "substantial contemporaneity of event and statement negat[e] the likelihood of deliberate o[r] conscious misrepresentation" (803 F.R.E., advisory committee's notes). The assumption is that contemporaneous statements have three safeguards that normal hearsay evidence lacks: a reduced chance of conscious misinterpretation, a reduced chance of memory errors, and the near universal presence of a third party to corroborate the statement (Bellin, 2011, p. 333). Courts seem to be conscious of the underlying folk psychology assumptions behind the exception when deciding how long of a lapse is allowed. For example, in *United States v. Campbell*, in deciding to admit the statement under rule 803(1), the judge reasoned, "any delay between the event and the telephone call does not suggest that there was time for Wilson to consciously reflect and to fabricate a story" (*United States v. Campbell*, 1991, p. 1261). If at least some judges consider how long it takes to "consciously reflect and to fabricate a story," a more precise understanding of how long these processes take may provide greater legitimacy and consistency to admissibility decisions.

There are three underlying assumptions behind the PSI that science may be able to assess. The first, and most critical, is whether contemporaneity is a safeguard against deceit; is it truly harder to lie about an event you are currently viewing than a past event? The second question is, if contemporaneity is a safeguard, at what point does it lose its efficacy? In other words, how long after an event occurs does it become more like lying about a past event than lying about a current event? Third, focusing on the presence of a third party and the detectability of lies, are lies about a contemporaneous event easier to detect than lies about past events? The next section discusses current theories of lie generation which help shed some light on the possible answers to these questions.

Lie Generation

Deception is generally defined as "a deliberate attempt to convince someone of something the liar believes is untrue" (Depaulo, Kashy, Kirkendol, Wyer, & Epstein, 1996; Vrij & Ganis, 2014; Walczyk, Harris, Duck, & Mulay, 2014). This can include bald face lies, lies of omission, or subtle misdirection. A lot of research has been done on the process of lying and on lie detection, but, unfortunately, none of the research can definitively answer any of our three questions about the PSI, though they do make some of the assumptions more or less likely.

Theories of Lie Generation

One of the earliest theories of lie generation is the psychologically focused four factor theory (Zuckerman, Depaulo, & Rosenthal, 1981), and many lie detection techniques have targeted steps laid out by this theory (Walczyk, Igou, Dixon, & Tcholakian, 2013). The theory postulates that lying necessitates (a) generalized arousal, (b) anxiety, guilt, and other negative emotions, (c) cognitive components such as increased cognitive load, and (d) liars' attempts to conceal their deceit through control of verbal and non-verbal cues (Walczyk et al., 2013; Zuckerman et al., 1981). This theory has proven extremely useful in the development of lie detection techniques that depend on detecting increased arousal (Palmatier & Rovner, 2015) or increasing cognitive load to challenge liars (Vrij, Granhag, & Porter, 2010; Walczyk et al., 2013) but postulates little about the underlying cognitive processes and nothing about how temporal divorce between viewing the to-be-lied about event and the telling of the lie.

A more complete version of discourse production still guides much of deception research today (T. Levine, 2014; McCornack, 1997). The theory proposes 4 steps of lie production: (a) the liar-to-be is presented with a complex social situation in which truth-telling would entail significant personal, professional, or relational costs; (b) the liar-to-be weighs the cost of truth and deception and decides to lie; (c) the liar-to-be constructs a lie, entailing cognitive load and increased anxiety; and (d) the now liar presents his information to his audience with both verbal and nonverbal cues with an increased probability of “tells” due to the cognitive load and anxiety produced by step (c). This process is top-down with a single, linear, sequential flow (T. Levine, 2014; McCornack, Morrison, Paik, Wisner, & Zhu, 2014). Importantly, this implies that both the truth must be activated and also that the decision to lie occurs prior to the production of the narrative. The latter of the two has already been proven to be false in certain circumstances (McCornack, 1997; O’Keefe, 1981) whereas the former remains a central tenet of researchers today (T. Levine, 2014; McCornack et al., 2014).

Another more recent popular theory of lie generation focuses on the truth suppression step but remains primarily psychologically focused with little emphasis on the underlying cognitive mechanisms. (T. Levine, 2014). The Truth-Default-Theory (TDT) assumes both that people default to telling the truth and that listeners default to assuming truthfulness of statements, and that both of these traits are adaptive in a majority of circumstances (T. Levine, 2014). While TDT lays out 14 propositions central to lie generation from general tendencies, to specific motivations and communication techniques, to best means of detection, at its core it boils down to proposition 5 that “most people are honest unless the truth thwarts some desired goal or goals” (T. Levine, 2014). Importantly, while left unsaid, this requires the truth to be initially activated to then be suppressed if inconsistent with the actor’s goals.

The Activation-Decision-Construction-Action Theory of lie generation postulates more specific cognitive processes of lying while building upon the four-factor model (Walczyk et al., 2014). While it's four steps are similar, "(a) activation of the truth, the (b) decision whether and how to alter deceptively the information shared, (c) construction of a deception, and (d) action [acting sincere while delivering a lie]" (Walczyk et al., 2014), it further theorizes on the underlying cognitive processes. The Activation-Decision-Construction-Action Theory breaks lying into 4 components (Activation, Decision, Construction, and Action), further broken into 12 milestones (Figure 1), though it emphasizes that all steps occur "automatically, unconsciously, seamlessly, and in parallel" (Walczyk et al., 2014). Importantly, this model also stresses the automatic retrieval of the truth from long term memory into working memory, the necessary maintenance of the truth plus the construction of a lie within working memory, the selection of response, and the inhibition of the truth (Walczyk et al., 2014). This theory has all of the common components of lie generation theories with a particular stress on the importance of conflict monitoring and truth suppression, theory of mind through a central executive function (Apperly, Samson, & Humphreys, 2009; Walczyk et al., 2014), the burden on working memory (Apperly, Back, Samson, & France, 2008; Walczyk et al., 2014), and increased cognitive load within a limited cognitive resource environment (Ekman, 2001; Walczyk et al., 2014).

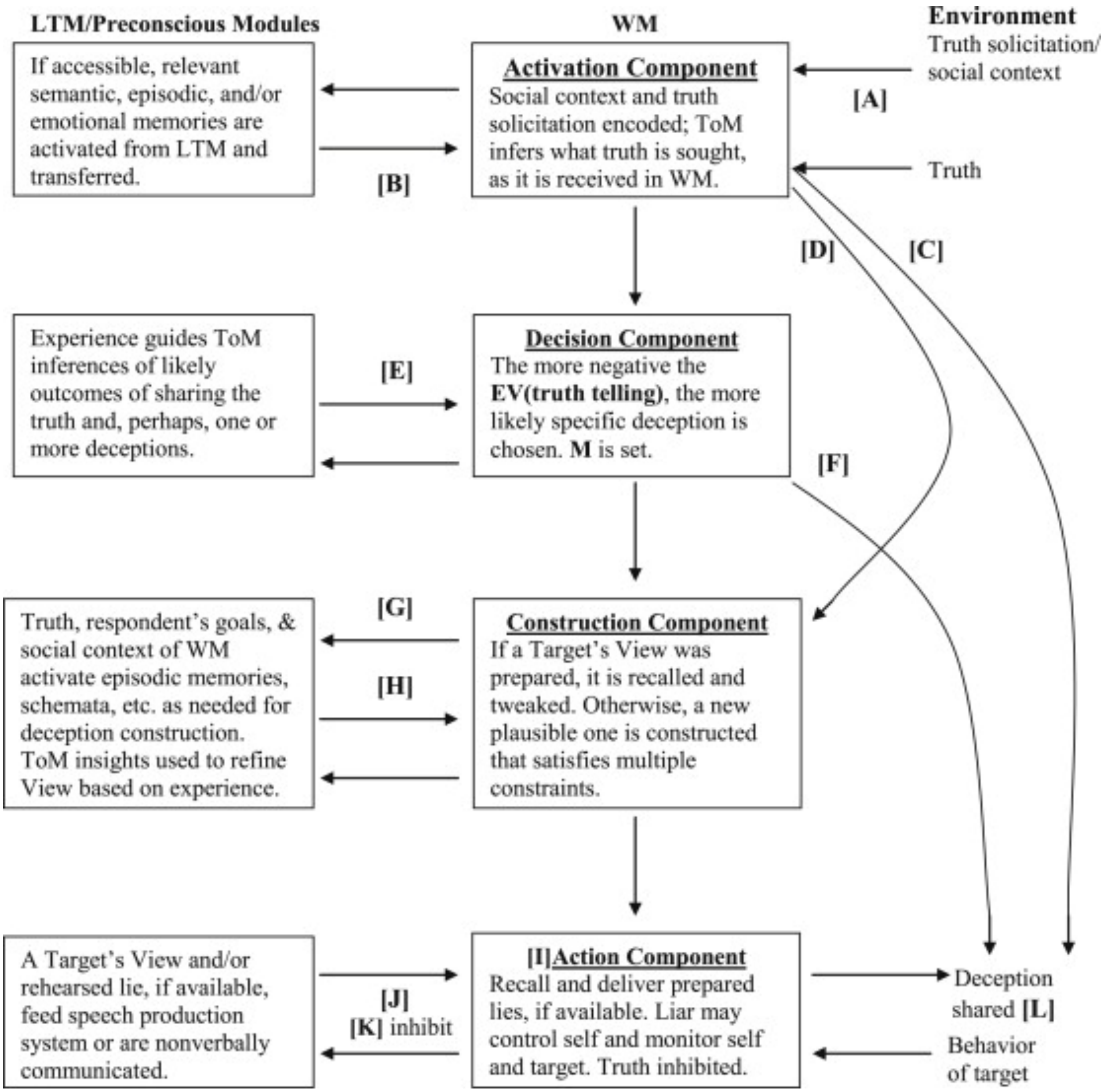

Figure 1.The flow of information and processing among the four components [of Activation-Decision-Construction-Action Theory]. Reprinted from New Ideas in Psychology with permission from Elsevier.

Other researchers seeking to move beyond the simple cognitive load approach have looked to integrate theories of lie generation within the theoretical frameworks of other fields. For example, Sporer (2016) proposed a model of lie generation with a greater emphasis on working memory and anchored in Baddeley's 2000 and 2012 working memory models (Baddeley, 2000, 2012; Sporer, 2016). In this model, increased cognitive load is taxing to liars because the central executive from Baddeley's working memory model is involved not only in long term memory retrieval but also control of actions, leading to increased behavioral tells of nervousness (Sporer, 2016). Under this view, the PSI's assumption may be accurate because liars rely on general schema to create their lie, meaning that truthful accounts may actually contain more schema inconsistent information but also that this difference may decrease with time as more schema-irrelevant details are forgotten (Sporer, 2016; Tuckey & Brewer, 2003).

The Information Manipulation Theory 2 theory also relies in part on Baddeley's working memory models (Baddeley, 2000, 2012; McCornack et al., 2014) and also draws on theories from the problem solving and speech production literatures (Chang, 2002; Chang, Dell, & Bock, 2006; J. O. Greene & Herbers, 2011; McCornack, 1997; Nii, 1986). Information Manipulation Theory 2 moves beyond simple cognitive load theory by suggesting that increased cognitive load is not inherent to deception, but, instead, varies depending on the information activated in memory and the degree of freedom in the problem-solving scenario (McCornack et al., 2014). Information Manipulation Theory 2 views memory and problem solving as the central premises of lie generation so much so its creator states "the future study of deception (and the positing of corresponding theories) should be rooted in the study of memory and problem solving" (McCornack et al., 2014). In addition to moving beyond the lie/truth false dichotomy, this theory stresses that lie construction is likely to be composed of information already retrieved from long term memory into working memory through attentional focus, rather than through analysis of strategic plausibility (McCornack et al., 2014). In other words, the chosen lie is driven more by memory than higher order deductive reasoning (McCornack et al., 2014).

Importantly for the assumptions of the PSI, Information Manipulation Theory 2 assumes an opportunistic problem-solving model in which the decision of whether or not to lie may occur and be re-evaluated part way through an utterance, rather than being preplanned (Chang et al., 2006; McCornack et al., 2014). The construction of discourse, truthful or deceptive, is piecemeal and guided by ongoing mini cycles of cognitive activity (Baars & Franklin, 2007; McCornack et al., 2014). This suggests that it may not be the temporal delay between the to-be-lied about event and the question, but the unexpectedness of the question (T. R. Levine et al., 2014; McCornack et al., 2014), which would correlate with the passage of time for salient events such as crimes you are motivated to lie about.

Furthermore, Information Manipulation Theory 2's incorporation of the Chang and Dell models of speech production, in which the primary influence on the incremental production of speech is memory salience and ease (McCornack et al., 2014), suggests that deceptive statements will typically have fewer details than truthful statements, a common finding in lie detection (McCornack, 1997; Turner, Edgley, & Olmstead, 1975). Information Manipulation Theory 2 also predicts that the commonly noted "tell" of longer pauses in speech production should only occur for a subset of lies when the activated truth is deemed inappropriate to disclose but no associated active information offers a suitable replacement (McCornack et al., 2014). The frequency of this scenario should increase with targeted questions which reduce the degrees of freedom for an appropriate answer, such as during an effective interrogation (T. R. Levine et al., 2014; McCornack et al., 2014). Recent work has suggested that individuals can prioritize the encoding into visual long-term memory of stimuli over others, but that this comes at a cost to nonprioritized items (Sundby, Woodman, & Fukuda, 2019). This suggests that questions targeted at seemingly irrelevant details at the time of encoding may not be an effective means of interrogation as this could result in a false positive if the individual prioritized the other elements of the to-be-remembered scene at the expense of the asked about detail (Sundby et al., 2019).

The Sporer, Activation-Decision-Construction-Action Theory, and the Information Manipulation Theory 2 theories of lie generation all move beyond the four-factor theory and its kin of the 1980s and provide more empirically assessable claims (McCornack et al., 2014; Sporer, 2016; Walczyk et al., 2014). While they vary significantly in the process of motivation assessment and response selection, they all still center on the need to retrieve the truth from long-term memory and hold it in working memory prior to or while assessing whether to respond truthfully (McCornack et al., 2014; Sporer, 2016; Walczyk et al., 2014). This commonality provides the strongest point to assess the validity of the PSI's assumption; how does working memory load vary between lying about a past event, lying about a contemporaneous event, and truth-telling?

The Neural Circuitry of Deception

While the reviewed theories of lie generation vary in important ways, they share several key commonalities (Farah, Hutchinson, Phelps, & Wagner, 2014): inhibiting the truthful response, generating an alternative version, and holding two versions in working memory while regulating emotion (Farah et al., 2014), and, with the exception of the Information Manipulation Theory 2, increased cognitive load for lying. Studies attempting to elucidate the neural mechanisms of deception have focused on the regions involved in these steps.

Historically most theories of lie generation and methods of lie detection boiled down to the central axiom that lying is more cognitively demanding than truth telling, and many even stop here (Ellwanger, Rosenfeld, Sweet, & Bhatt, 1996; Sporer, 2016; Suchotzki, Verschuere, Bockstaele, Ben-Shakhar, & Crombez, 2017; Vrij, Fisher, Mann, & Leal, 2006). Many lie detection techniques have been centered on this central premise and view increasing cognitive load as a key to lie detection (Walczyk et al., 2013). This very idea is central to the cognitive interview technique popular in police departments today (Fisher & Geiselman, 1992) and is supported by numerous behavioral measures, such as increased reaction time for lying (Sheridan & Flowers, 2010; Suchotzki et al., 2017), increased verbal, nonverbal, and para-verbal "tells" when lying with increased cognitive load (Lancaster, Vrij, Hope, & Waller, 2013; Vrij, Fisher, & Blank, 2017), and self-report (Caso, Gnisci, Vrij, & Mann, 2005; Vrij, Semin, & Bull, 1996).

The cognitive steps of deception are thought to involve the medial frontal cortex (MFC), dorsolateral prefrontal cortex (DLPFC), the ventrolateral prefrontal cortex (VLPFC), and the anterior cingulate cortex (ACC) (Abe, 2009; Shawn E. Christ, Van Essen, Watson, Brubaker, & McDermott, 2009; Ganis, 2003; Spence et al., 2004). Numerous fMRI studies have found patterns of increased activity when lying compared to truth-telling similar to those found during complex cognitive tasks (Abe, 2009; Farahany, 2016; Spence et al., 2004). Several meta-analysis of fMRI studies of lie generation on a variety of paradigms suggest the importance of executive control (Abe, 2009; S. E. Christ, Van Essen, Watson, Brubaker, & McDermott, 2009; Spence et al., 2004). A meta-analysis by Christ et al. (2009) compared regions with consistently increased activity during deception to those associated with three aspects of executive control: working memory, inhibitory control, and task switching (S. E. Christ et al., 2009). Their results showed significant overlap between regions involved in deception and executive control processes, but most prominently with working memory in the dorsolateral PFC and posterior parietal cortex.

They also found deceptive regions without overlap with any of their executive control paradigms, including the bilateral inferior parietal lobule, suggesting that deception may involve more than executive control processes (S. E. Christ et al., 2009). Similarly, other research has suggested that regions previously associated with deception per se may be more attributable to generalized processes such as memory retrieval, and could be associated with deception purely due to experimental design (Gamer, Klimecki, Bauermann, Stoeter, & Vossel, 2012). Recently, the premise that lying is *always* more cognitively demanding has been challenged (Depaulo et al., 2003; Yin, Reuter, & Weber, 2016). For example, a study by Yin et al. (2016) found that in spontaneous lie-scenarios where it is beneficial to lie, cognitive load, particularly in the fronto-parietal network, may actually be higher for truth-telling than lying due to the need to suppress self-interest motives.

Several studies have compared brain activity during different types of lies to help elucidate the underlying mechanisms (Ganis, 2003; Hu, Wu, & Fu, 2011). Ganis et al. (2003), for example, hypothesized that spontaneous and memorized lies would employ different cognitive mechanisms, with spontaneous lies drawing on semantic and episodic knowledge, and memorized lies retrieving previous memories. Episodic knowledge refers to retrieval of a past specific episode for reference, while semantic knowledge refers to the generation of a plausible answer set (Ganis, 2003). The researchers also hypothesized that generating lies within a scenario would require greater working memory load than isolated lies since the subjects would have to maintain and crosscheck more details. The study only compared the most extreme forms, spontaneous-independent and memorized-scenario, and found increased activation in the anterior middle frontal gyrus, the fusiform/parahippocampal gyrus, the right precuneus, and the left cerebellum in both deception types, suggesting at least some common circuitry to deception (Ganis, 2003).

The researchers, also, however, found several differences in activation between the lie types, suggesting that there may be some differences in how individuals spontaneously generate isolated lies and how they recite memorized lies within a coherent scenario, a difference of particular importance for the PSI, and hypothesized two distinct cognitive processes. They theorized the memorized-scenario lies rely primarily on episodic memory retrieval and that memorized lied are more difficult to retrieve due to fewer retrieval cues, as shown by the increased activity compared to truth telling in the bilateral superior BA 10 (Grady, 1999), precuneous (Krause et al., 1999), and cerebellum (Andreasen et al., 1999) and in the right inferior BA 10 (Grady, 1999) compared to both truth telling and spontaneous-independent lies (Ganis, 2003). memorized-scenario liars then fabricate a lie and encode the lie into episodic memory as shown by increased activity in the parahippocampal cortex (Wagner, Desmond, Glover, & Gabrieli, 1998).

Spontaneous-independent lies, on the other hand, are far more complex and require increased retrieval of episodic *and* knowledge, as shown by the increased activation of the bilateral superior (Grady, 1999), the precuneus (Krause et al., 1999), and the cerebellum (Andreasen et al., 1999), visual imagery, as shown by the increased activity in the right cuneus (Kosslyn, Ganis, & Thompson, 2001), working memory, as shown by the increased activity in the fusiform gyrus and cuneus of the posterior visual cortex (Grady, 1999), response monitoring via checking your lie for plausibility, as shown by the increased activity in the anterior cingulate (Ruff, Woodward, Laurens, & Liddle, 2001), and encoding the lie into episodic memory, as shown by the increased activity in the parahippocampal cortex (Wagner et al., 1998).

These findings strongly support the assumptions of the PSI suggesting that spontaneous, or contemporaneous, lies are far more cognitively demanding than previously memorized lies. They did not, however, find any behavioral differences between the conditions, with no significant differences in error rate and they did not measure reaction time (The researchers did measure reaction times for a more simplistic yes/no paradigm and found slower reaction times for spontaneous-independent than memorized-scenario lies, but this difference was not significant and both reaction times were still under one second) (Ganis, 2003). This study also did not measure the type of lie most pertinent to the PSI, a spontaneous lie *within* a coherent scenario, leaving our question of whether contemporaneity provides a safeguard against deceit unanswered.

EEG Measures of Deception

By far the most prominent EEG measure of deception is the increased P300 to concealed information in the Guilty Knowledge test paradigm, also known as the Concealed Information Test (Ellwanger et al., 1996). The Guilty Knowledge test began as a procedure with electrodermal measures and can be used to identify concealed information. For example, if participants are asked to steal an item and then are shown images of items that might have been stolen, they show a greater electrodermal response to the item they stole compared to the others (Lykken, 1959).

Modern versions of the Guilty Knowledge test use the odd-ball sensitivity of the P300 to detect covertly held information instead of the electrodermal response. The P300 is sensitive to the presentation of a low probability salient stimuli (Duncan-Johnson & Donchin, 1977). The P300 is preferred because it is a more direct measure of stimulus processing rather than an indirect measure via the autonomic nervous system response (ANS) (M. M. Johnson & Rosenfeld, 1992). Participants (and hypothetically suspects) are presented a series of stimuli some of which are in a low probability category and others that are high probability. Concealed information, information the participant knows but is denying or a previously seen stimuli they are deceitfully categorizing as new, will show a P300 similar to the low probability category (Ellwanger et al., 1996). Versions of the Concealed Information Test have been applied to more ecologically valid scenarios, such as identifying with 89% accuracy, regardless of the participant's response, whether a participant pretending to be a job applicant has or has not committed any of 8 asked about antisocial behaviors (M. M. Johnson & Rosenfeld, 1992). It is important to note the P300 within the Guilty Knowledge test paradigm does not index "deceit," but rather memory/no memory of the probe regardless of the participant's response (M. M. Johnson & Rosenfeld, 1992).

While the P300 generally is understood to be sensitive stimulus probability, task relevance of the stimulus, and stimulus evaluation (Folstein & Van Petten, 2008; R. Johnson & Donchin, 1980), further research has broken into subcomponents sensitive to different measures and with different scalp distributions (Folstein & Van Petten, 2008). In general, the P300 can be broken into two subcomponents (Folstein & Van Petten, 2007; but see Spencer, Dien, & Donchin, 2001 identifying three subcomponents). The P3a has a fronto-central distribution and is sensitive to rare (by category) or significant events, suggesting a role in attention (Breton, Ritter, Simson, & Vaughan, 1988; Folstein & Van Petten, 2011; R. Johnson & Donchin, 1980). The P3b, sometimes called the late positive component, has a parietal distribution and is believed to be involved in memory updating (Folstein & Van Petten, 2008; Spencer et al., 2001). The P3b is often associated with a N2 wave over parietal, temporal, and occipital electrode sites, sometimes called the anterior or target N2 (Folstein & Van Petten, 2008; Ritter, Simson, Vaughan, & Macht, 1982). This N2 is associated with the degree of attention required for visual processing (Suwazono, MacHado, & Knight, 2000) and has been found to increase to deviant stimuli when cognitive load increases (Alho, Woods, Algazi, & Näätänen, 1992).

A series of EEG studies have moved beyond the Guilty Knowledge test and its associated ERPs and begun to pull apart the time course of the potential deception circuitry and has associated several ERPs with some of the cognitive steps. Johnson et al. has reported reduced pre-responsive potential (PRP) 100ms prior to response during deception trials. This is believed to be associated with strategic monitoring and conflict resolution (R. Johnson, Barnhardt, & Zhu, 2005). Deception can also affect early attention and executive function related ERPs with Hu et al. finding increased N1 and N2 amplitudes during deception (also thought to reflect response monitoring) (Hu et al., 2011). Differences have also been observed post response, with Johnson et al. finding increased negativity in the medial frontal negativity (MFN) 0-100 ms post-response and is thought to be associated with response monitoring and conflict detection and is near the ACC (R. Johnson, Barnhardt, & Zhu, 2004). An earlier study by Johnson et al. also found reduced amplitude in the P300, or as he calls it the Late Parietal Component (LPC), as late as 500-700ms post-response (R. Johnson, Barnhardt, & Zhu, 2003). These experiments have begun to tease apart the time course of lie generation and have identified useful markers of brain activity for future studies.

Given the importance of working memory in lie generation, it is worth discussing the contralateral delay activity (CDA) as another ERP of interest in the present work. The CDA is a well-studied electrophysiological component which indexes the number of items maintained in working-memory (Vogel & Machizawa, 2004; Vogel, McCollough, & Machizawa, 2005; Wang, Rajsic, & Woodman, 2018). The CDA is measured over parieto-occipital sites and is the difference wave of the contralateral minus the ipsilateral activity of a to-be-remembered array (Vogel & Machizawa, 2004; Vogel et al., 2005; Wang et al., 2018). It increases as the number of items being held in working memory increases before reaching an asymptote at working memory capacity (Vogel & Machizawa, 2004; Vogel et al., 2005; Wang et al., 2018). The CDA has been shown to be present and load dependent across a variety of stimulus types varying from oriented bars (Machizawa, Goh, & Driver, 2012) and simple shapes (Fukuda, Awh, &

Vogel, 2010) to photographs of real-world objects (Brady, Störmer, & Alvarez, 2016) and alphanumeric stimuli (Rajsic, Burton, & Woodman, 2019). The event-related slow wave is a closely related non-lateralized measure that shares many of the same traits (Fukuda, Mance, & Vogel, 2015). If individuals do hold multiple representations of a to-be-lied about stimuli in working memory, the CDA or event-related slow wave may be able to detect the increase.

Reaction Time, Behavioral Paradigms, and Catching Liars

Another line of study that may have implications for the validity of the PSI includes studies that have evaluated how long it takes to lie (Abe, Suzuki, Mori, Itoh, & Fujii, 2007; J. O. Greene, Dan O'Hair, Cody, & Yen, 1985; Sheridan & Flowers, 2010; Spence et al., 2001). While substantial variation exists (J. O. Greene et al., 1985; Sheridan & Flowers, 2010), most studies converge around an additional 200–400 ms for lying compared to truth telling (Abe et al., 2007; Karim et al., 2010; Mameli et al., 2010; Sheridan & Flowers, 2010; Spence et al., 2001). This small of a delay in reaction time raises obvious concerns over the validity of the PSI's underlying assumption. If individuals can fabricate lies in less than half of a second, perhaps contemporaneity is not as strong of a safe guard as the rule and many judges assume. Importantly, however, these studies often test previously instructed lies (Mameli et al., 2010), simple yes or no lies (Spence et al., 2001), or lies told with significant advanced notice (Abe et al., 2007). It may be that lying within a coherent story line, where the fabricated element must assimilate with the truthful elements, takes significantly longer than simply reciting a pre-instructed lie or lying with advance notice, potentially leaving the rule's underlying assumption about the difficulty of deceit intact.

One of the major critiques of the majority of behavioral paradigms studying deception is the lack of actual deceit (J. D. Greene & Paxton, 2009). Most studies of lying involve "instructed" lies where the participant is told to lie by the researcher (Abe et al., 2007; Karim et al., 2010; Mameli et al., 2010; Sheridan & Flowers, 2010; Spence et al., 2001). This lack of actual deceit is a major confound since the subjects may not perceive their behavior as "dishonest." This is especially problematic since many previously assessed signs of lying may actually measure physiological responses to fear and guilt, rather than actual lie generation (J. D. Greene & Paxton, 2009). These cues may not be present at all, or to a lesser extent, in instructed lies since the participant may not feel guilt or fear to the same degree.

Greene and Paxton (2009) addressed this shortcoming by developing a paradigm where subjects believed they were actively deceiving the researchers. Subjects were told that they were participating in an experiment on the paranormal ability of predicting the future and asked to predict the outcome of a coin flip and economically rewarded for guessing correctly. They had to reveal their guess either before the flip, no opportunity to lie, or after, giving the participants an opportunity to lie. Liars were identified statistically as those individuals who performed dramatically higher than chance. The researchers found no increased activity when subjects chose to tell the truth but found heightened activity in control-related regions of the prefrontal cortex in subjects who behaved dishonestly. The degree of heightened activation was correlated with the presumed number of dishonest responses (J. D. Greene & Paxton, 2009). These findings suggest that, consistent with the prior literature, lying does require a heightened cognitive load, probably due to the inhibition of the truthful response. Furthermore, it suggests a region of differential activation when subjects are engaging in active deceit.

Several other studies have also examined how successful people are at detecting lies. The overwhelming majority of these studies, however, have found that participants perform no better than chance at detecting deceit (Farah et al., 2014). None of these studies, however, have explicitly assessed contemporaneous lies, leaving open the possibility that there is something unique about this lie type that is more obvious to a third party observer.

Conclusion

A survey of the literature makes clear that further research is needed to directly assess the validity of the assumptions behind the PSI. The reviewed studies, while informative and allowing the formation of hypotheses, do not establish whether contemporaneity is or is not a safeguard against deceit, provide little basis for deducing when contemporaneity ends, and do not answer whether third parties can reliably catch contemporaneous lies. Future studies need to probe three questions while also improving ecological validity: (1) whether contemporaneity is a sufficient safeguard against deceit; (2) if so, at what time point does this safeguard cease to be effective; and (3) are individuals more capable of detecting lies about contemporaneous events than past events. The next two chapters introduce novel research directly assessing these questions.

The assessment of these assumptions could have a direct impact on the PSI rule. If the assumptions are proved valid, the rule may enjoy increased legitimacy. Furthermore, a better understanding of the nature of the contemporaneity safeguard may result in a more consistent application of the "contemporaneous" requirement. If the assumptions are proved false, there are several possible scenarios. Policy makers may choose to keep the rule due to a lack of viable alternatives, they may consider a change but opt against it out of an efficiency interest or other motive, or, they may craft a new rule based off a more sound understanding of the cognitive processes underlying the production and processing of lies about contemporaneous events. More broadly, if neuroscience can enrich the conversation around the PSI, it may be able to do so for many evidentiary and procedural rules. Should this prove to be the case, neuroscience should begin to be looked to as a valuable tool in assessing and improving procedural rules premised on cognitive processes.

Next, I will discuss the findings from two experiments which do not support the traditional cognitive model of lying, which requires maintaining multiple representations in working memory, but ultimately support the operation, if not the reasoning, of the PSI. Our findings suggest that Individuals do not hold two representations of a to be lied about item in working memory, at least as indexed by the CDA. Instead, individuals may ignore to be lied about stimuli. A delay may or may not be necessary to implement this strategy but individuals can implement it with more complex stimuli and when deciding whether to lie.

CHAPTER 2

Does Lying Require More or Less Working Memory?

Introduction

Most lie generation models and lie detection techniques depend on the core assumption that lying is more cognitively demanding and requires a higher working memory load (WM) than truth-telling as individuals maintain both a truthful and a deceitful representation of the to be lied about stimuli in WM (Farah et al., 2014; Christ et al., 2009). This assumption, however, also has real world impacts through its implicit adoption in the Federal Rules of Evidence (FRE), one of the legal system's most important and complex sets of procedural rules crucial to the success of broad legal policy (Weinstein & Berger, 2008). One of these rules, the Present Sense Impression (PSI), rests on the core assumption that people are less able to lie about a contemporaneously viewed event than a past event and allows normally inadmissible evidence to be seen by the jury based on this assumption. Recently, some models of lie generation have begun to question whether lying is inherently more cognitively demanding and working memory intensive or whether this is only generally true and a product of experimental paradigms (Gamer et al., 2012; McCornack et al., 2014). We present the results of an electroencephalography experiment which suggests that under at least certain circumstances lying is *less* working memory intensive and that while contemporaneity may not be a safeguard against deceit, per se, the functioning of the PSI may be well suited to the behavioral and cognitive realities of lying in the moment versus after a delay.

If these assumptions are wrong, not only do we have a flawed theory of lie generation, but the rules of evidence may fail to promote the policy objectives of the FRE and might actually undermine the legal system's goals and result in injustices. Given the foundational importance of these assumptions in designing effective rules, it is critical that they be as accurate and as well founded as possible. While neuroscience cannot definitively recommend for or against any given rule because crafting a rule involves policy decisions beyond the firing of neurons, neuroscience can help the legal system assess the accuracy of the psychological assumptions underlying various evidentiary rules and can better inform policy makers. This paper demonstrates how neuroscience studies specifically targeting the underlying assumptions in the rules can benefit both fields of studies by better informing legal policy makers and improving our understanding of core psychological processes.

Method

Participants

All participants gave written informed consent according to procedures approved by the Vanderbilt University Institutional Review Board. All volunteers self-reported that they were neurologically normal, had normal or corrected-to-normal visual acuity, and were not color-blind. Data from 2 participants with fewer than 75 artifact free trials were excluded from analysis, leaving 31 participants in the sample.

Stimuli

The stimuli were generated and presented in MATLAB using the Psychophysics Toolbox (Brainard, 1997; Pelli, 1997). Participants were seated approximated 60 cm from the CRT monitor. A white fixation point was presented in the center of the screen and subtended 0.48 x 0.48° of visual angle. Cues were presented in the center of the screen and subtended 0.95 x 0.48° of visual angle and were one of two colors, red or white, depending on the task and condition (Yxy values: red, x = 0.553, y = 0.333, 15.7 cd/m^2; white (x = 0.275, y = 0.304, 65.1 cd/m2). Each square subtended 0.95 x 0.95° of visual angle, and the color was chosen from a set of 4 highly discriminable colors [red (x = 0.549, y = 0.385, 16.3 cd/m2), green (x = 0.309, y = 0.494, 51.3 cd/m2), blue (x = 0.164, y = 0.124, 13.9 cd/m2), yellow (x = 0.369, y = 0.466, 58.6 cd/m2)]. Stimuli were presented on a grey background (x = 0.275, y = 0.308, 28.7 cd/m^2). The array could extend a maximum of 8.1° from fixation.

Task

The task in experiment one was designed so that the to-be-reported objects elicited the CDA (Figure 2). Individuals were presented with a fixation cue for 250ms plus a jitter ranging from 1000-1400ms so that participants couldn't know the exact trial start time and to prevent alpha-band entrainment to the stimulus sequences across trials. A colored arrow was then displayed for 250ms with the direction indicating which side of the array will be probed and they should remember and color, counterbalanced across participants, indicating whether to respond truthfully or deceitfully. Following a 250ms fixation point a memory array made up of either one- or two-colored squares was displayed for 250ms. Next, following either a 500ms (contemporaneous condition) or 3000ms (delay condition) retention interval, a white probe would appear in the location of one of the squares from the cued side of the array. The participants reported by button press the color of the square from that location either truthfully or deceitfully depending on the color of the arrow.

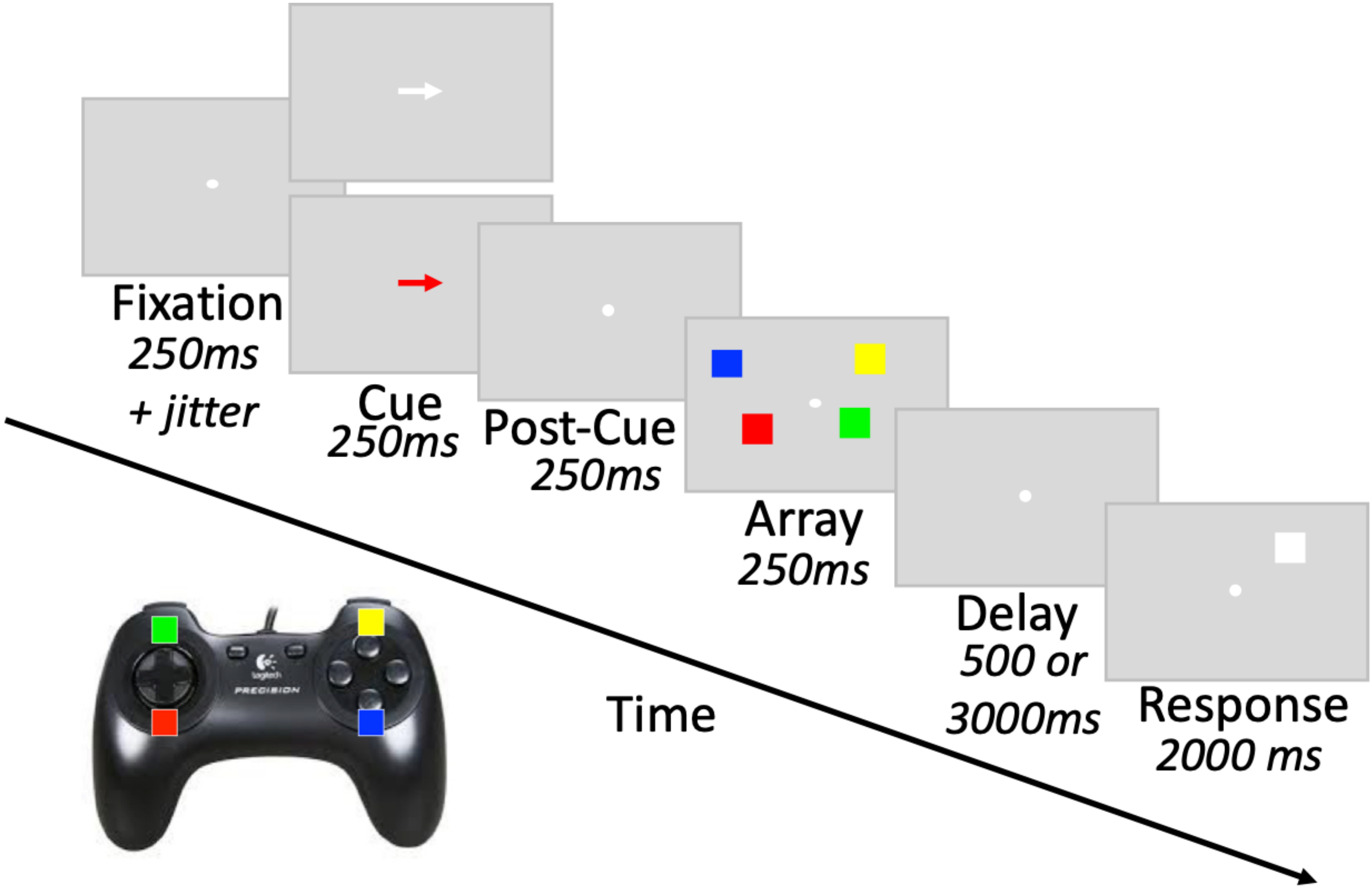

Figure 2. Stimuli timing and presentation. The arrow direction indicated which side of the array to remember and arrow color indicated whether to indicate truthfully or deceitfully. Color significance was counterbalanced across participants. CDA was measured for 300-700ms from array onset.

EEG Data Acquisition & Analysis

The EEG data were recorded using a right-mastoid reference and were referenced off-line to the average of the left and right mastoids. We used the international 10-20 electrode sites (Fz, Cz, Pz, F3, F4, C3, C4, P3, P4, PO3, PO4, O1, O2, T3, T4, T5, and T6) and a pair of custom sites, OL (halfway between O1 and T5 and OR (halfway between O2 and T6). Eye movements were monitored using electrodes placed 1 cm lateral to the external canthi for horizontal movement and an electrode placed beneath the right eye for blinks and vertical eye movements. The signals were amplified with a gain of 20,000, band-pass filtered from 0.01 to 100 Hz, and digitized at 250 Hz. Trials accompanied by horizontal eye movements (>30 μV mean threshold across observers) or eye blinks (>75 μV mean threshold across observers) were rejected before further analyses.

ERP Analysis

CDA

To examine the contralateral delay activity during lie generation and memory maintenance, we time-locked waveforms to the onset of the memory stimuli (Figure 2) and examined the ERPs recorded from -200 to 700ms following the onset of each memory stimulus. A shorter window then the 1000ms window commonly used in previous experiments (e.g. Vogel, McCollough, & Machizawa, 2005) was used due to the constraints of a contemporaneous condition. These ERP epochs were baseline corrected to the mean amplitude -200 to 0 ms relative to the stimulus onset. Difference waves were calculated across four electrode pairs (PO3/PO4, O1/O2, OL/OR, and T5/T6) by subtracting the ipsilateral activity from the contralateral activity relative to the to-be-remembered side of the array (Rajsic et al., 2019; Wang et al., 2018). Statistics were performed in JASP on the baseline-corrected but unfiltered data (JASP, 2018). For visualization, all figures display data passed through a 30Hz low pass filter.

Results

Behavior

Reaction Time

As shown in Figure 3, individuals were faster to respond when given a delay ($p < 0.001$, $F(1,30) = 100.99$) and when responding to an array with one item compared to two ($p < 0.001$, $F(1,30) = 167.67$). Our findings do not show subjects responded more slowly when lying compared to truth-telling, suggesting that previous reports of such an effect may not be reliably observed across different tasks and stimuli (Sheridan & Flowers, 2010). Instead, individuals were actually found to be faster when telling the truth rather than lying. Our results do, however, support our hypothesis of a distinct cognitive strategy when lying after a delay compared to responding contemporaneously, as shown by a significant three-way interaction between delay, response, and item number with individuals slowed less by increased item number when lying after a delay ($p < 0.001$, $F(1,30) = 15.98$).

Specifically, a repeated measures ANOVA with delay, response, and item number as between-subjects factors found a significant main effect of delay ($p < 0.001$, $F(1,30) = 100.99$), response ($p < 0.001$, $F(1,30) = 42.62$), item number ($p < 0.001$, $F(1,30) = 167.67$). There were also significant interactions between delay and response ($p < 0.001$, $F(1,30) = 17.48$), delay and item ($p < 0.001$, $F(1,30) = 62.23$), response and item ($p < 0.001$, $F(1,30) = 48.70$), and delay, response, and item ($p < 0.001$, $F(1,30) = 15.98$).

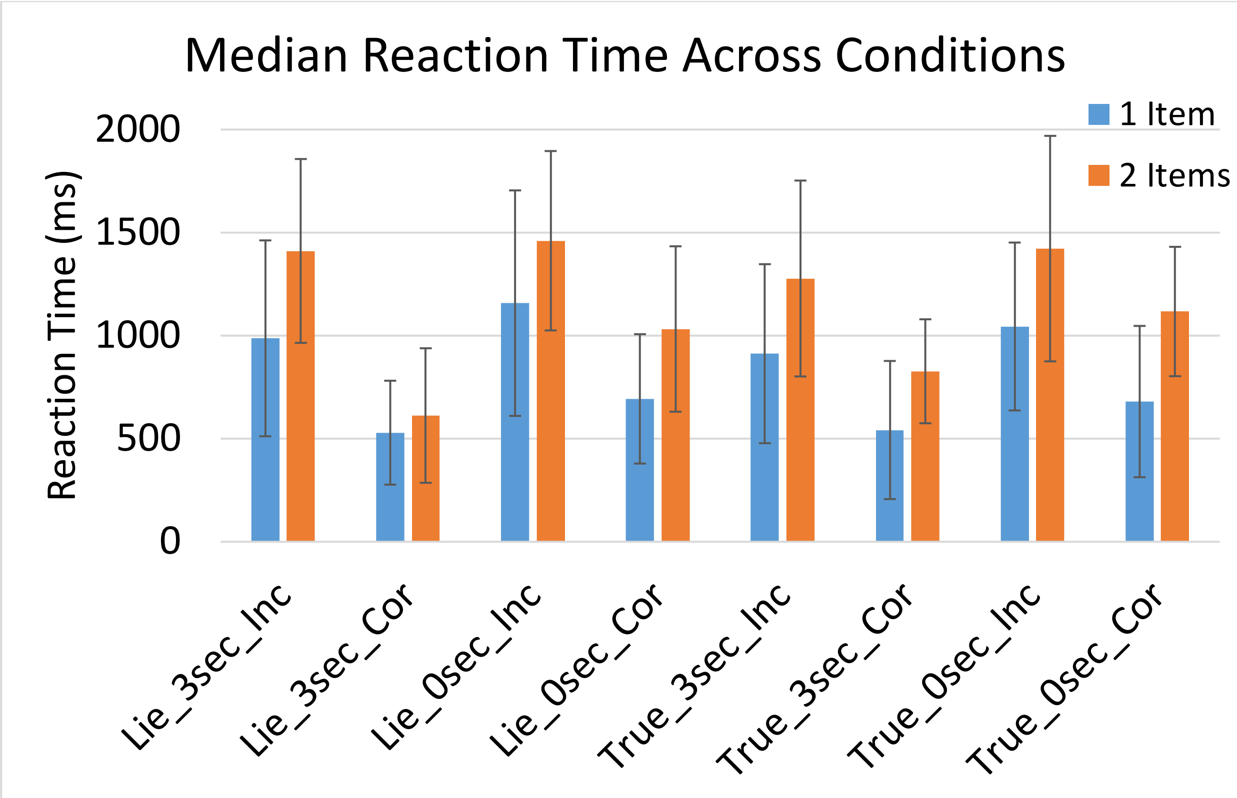

Figure 3. Median reaction time by condition. Individuals were faster to respond when given a delay and when responding one item arrays. There was no main effect of response type but there was a significant three-way interaction between delay, response, and item number with individuals slowed less by increased item number when lying after a delay.

Error Rate

As shown in Figure 4, individuals made more errors with two item arrays than one ($p < 0.001$, $F(1,30) = 86.388$) and in the contemporaneous condition ($p < 0.036$, $F(1,30) = 4.799$). Surprisingly, however, there was a significant main effect of response type with participants making significantly *fewer* errors when lying compared to truth telling ($p < 0.024$, $F(1,30) = 5.653$). This seems to be driven primarily by a drop in the error rate when lying compared to truth telling after a delay, as shown by a significant interaction between delay and response ($p < 0.001$, $F(1,30) = 24.006$). The same three-way interaction observed in the reaction time data was also seen in error rate with participants' error rates increasing less when going from a one to two item array and lying after a delay ($p < 0.001$, $F(1,30) = 13.479$), further strengthening the argument that individuals are employing a different cognitive strategy when lying after a delay compared to lying in the contemporaneous condition.

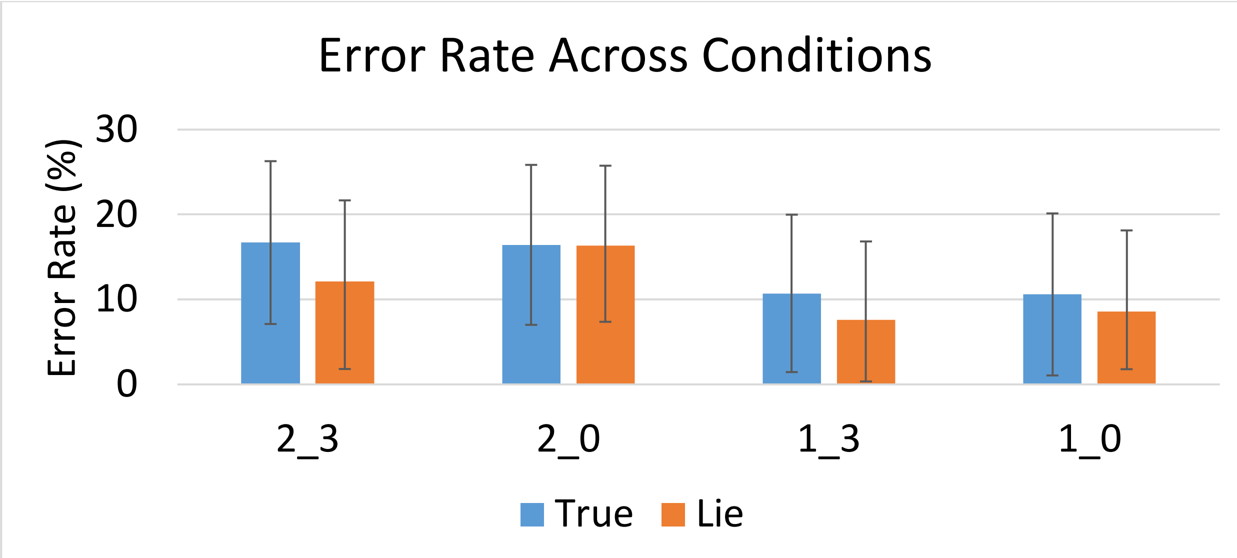

Figure 4. Error rate by Condition. Participants made fewer errors for 1 item arrays and when given a delay. There was a significant interaction between response and delay and the same three-way interaction observed in RT between delay, response, and item number.

ERPs

CDA

In line with the assumptions of the PSI, participants appear to utilize different cognitive mechanism to lie when in the moment or after a delay. As shown in Figure 5, contrary to what the majority of lie generation models would hypothesize, our findings suggest a *reduction* in working memory load, as measured by the CDA, when lying after a delay, but no differences in the CDA when lying without a delay. A repeated measures ANOVA with delay, response, and item number as between-subjects factors found a significant main effect of item number ($p < 0.001$, $F(1,30) = 50.452$) and a trend towards a significant main effect of response ($p = 0.094$, $F(1,30) = 2.990$). There was also a significant interaction between delay and response with a reduced CDA after a delay when lying, but not for truth telling ($p = 0.016$, $F(1,30) = 6.485$), and a trend towards a significant interaction between response type and item number with the CDA increasing less with item number when lying than when telling the truth ($p = 0.075$, $F(1,30) = 3.402$). These results seem primarily driven by a reduced CDA when lying about two items after a delay, suggesting that individuals may use a less working memory intensive cognitive strategy when lying about more complex stimuli and when given a delay. This was verified by preplanned paired t-tests which revealed that the CDA only significantly differed for lying compared to truth-telling when lying about two items after a delay ($p = 0.001$, $t(30) = -3.508$). All other comparisons were highly non-significant (True_2_0 – Lie_2_ 0: $p = 0.959$, $t(30) = 0.052$; True_1_0 – Lie_1_ 0: $p = 0.458$, $t(30) = -0.751$; True_1_3 – Lie_1_ 3: $p = 0.877$, $t(30) = 0.157$).

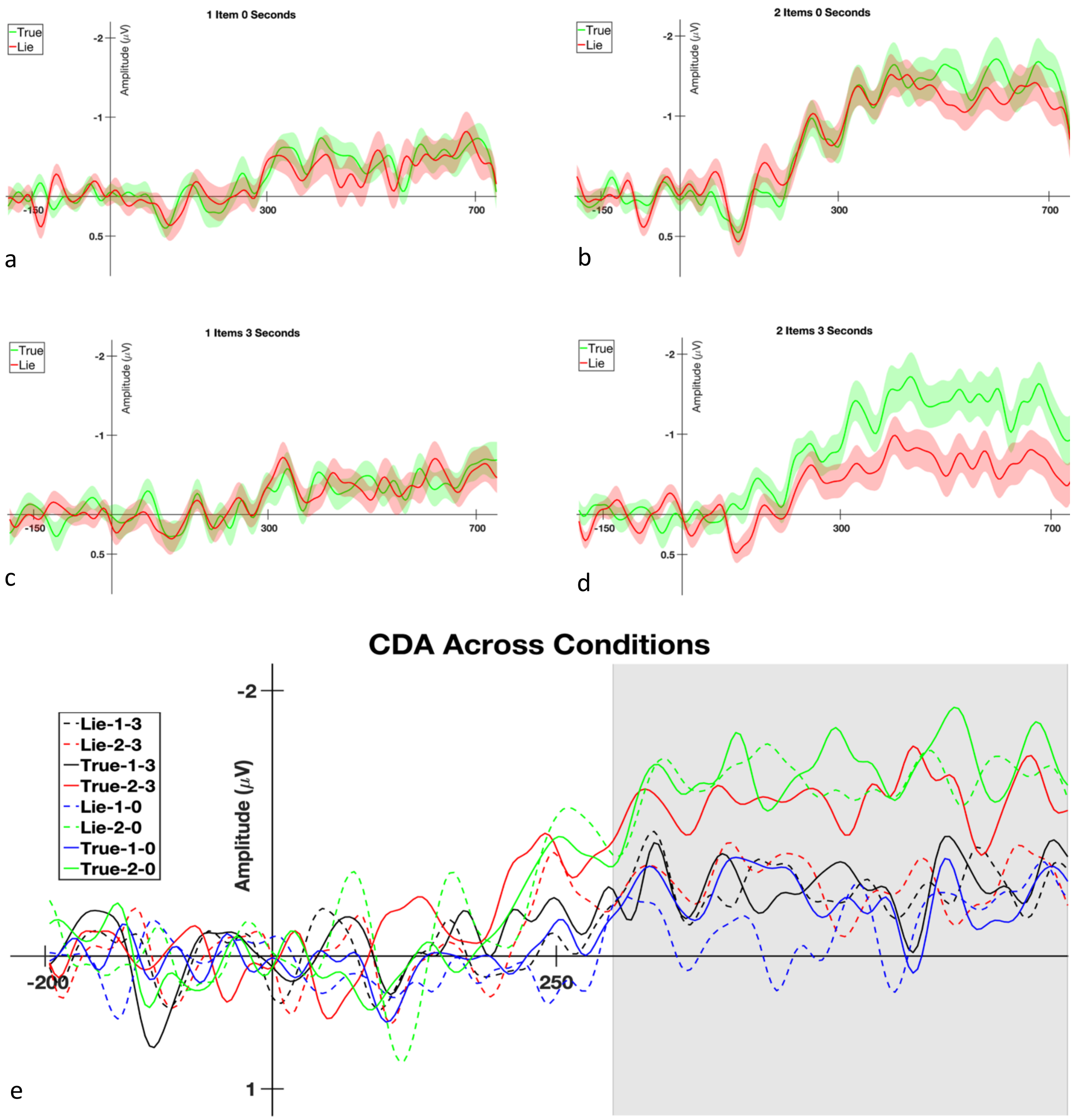

Figure 5. CDA Across Conditions. From top left to bottom right the figures show the CDA for (a) 1 item in the contemporaneous condition, (b) 2 items in the contemporaneous condition, (c) 1 item in the delay condition, (d) 2 items in the delay condition. (e) displays all CDAs for all items and conditions. The CDA increases with item number and trends towards increasing with truth-telling but this is primarily driven by an interaction between delay and response and a trend towards an interaction with response and item number with a reduced CDA after a delay when lying but not for truth telling and increasing less with item number when lying than when telling the truth. The CDA only significantly differed for lying compared to truth-telling when lying about two items after a delay. The shaded error represents the standard error.

Discussion

Our findings suggest that individuals do not *have* to maintain multiple representations of a stimuli in order to lie about it, as many theories of lie generation assume (S. E. Christ et al., 2009; Farah et al., 2014; Foerster, Wirth, Berghoefer, Kunde, & Pfister, 2019). Most lie generation models postulate the retrieval and maintenance of the truthful representation, followed by its inhibition, as a necessary pre-requisite to lie generation. Our results, however, suggest that while this may occur in many settings (S. E. Christ et al., 2009; Farah et al., 2014; Spence et al., 2004) it is not a pre-requisite to the lie generation process itself. Instead, in at least some circumstances individuals may actually drop the truthful representation from memory and only maintain the deceitful response, as shown by our reduced CDA for lying compared to truth-telling in the delay condition. This would reduce cognitive load and could result in fewer of the behavioral costs of lying. This may come at the cost, however, of worse memory for the truth and the event as a whole. Future studies should directly assess the memory for the truthful representation of the lied about stimuli following either contemporaneous lies or lies after a delay.

One of the shortcomings of our paradigm is the simplicity of the stimuli and task. First, while this may limit the generalizability of our findings, most lie generation models stipulate the maintenance of the truth as a *necessary* pre-requisite to lie generation, regardless of complexity. Our findings, therefore, suggest that while this may often, or even almost always, be true, it is not a necessary cognitive step. This finding fits in well with the Information Manipulation Theory 2 model of lie generation which stipulates that while lying is *often* more cognitively demanding and requires more working memory, this is not a necessary pre-requisite but a frequent co-occurrence (Gamer et al., 2012; McCornack et al., 2014). Furthermore, while our stimuli are more basic than many lie paradigms, its response scheme is actually more complicated than most with participants able to choose any of three possible lie responses, unlike frequently used paradigms such as previously instructed lies (Mameli et al., 2010), simple yes or no lies (Spence et al., 2001), or lies told with significant advanced notice (Abe et al., 2007).

Our findings also suggest that while the reasoning behind the PSI may be flawed, its functioning may be appropriate. While contemporaneity does not appear to be a safeguard per se against deception, the functioning of the rule may actually fit the behavioral and cognitive realities of the differences in how people lie about a contemporaneous event versus a past event. Our results suggest that individuals may switch from a working memory intensive, slower cognitive strategy when lying about a contemporaneous event to a faster, less memory intensive strategy when given a delay. This difference may result in more behavioral *tells* easily detected by a third-party listener, as shown by are increased error rates and reaction time, but a more complete representation of the event resistant to cross-examination like questions, as shown by no differences in the CDA between lying and truth-telling, when lying in the moment. Conversely, when lying after a delay there may be fewer behavioral tells detectable by a casual third-party listener, as shown by the reduced increase in reaction time and drop in error rate, but a less complete memory representation of the event making detection susceptible to cross-examination like questions, as shown by the reduced CDA for lying compared to truth-telling after a delay, when lying about a past event. Our results also suggest, however, that this switch can occur extremely rapidly, in as little as 3000ms in our paradigm, suggesting that the PSI exception should be constrained to true contemporaneity rather than merely substantial.

Conclusion

This article lays out original empirical research that helps fill the gap in the current scientific literature and suggests that maintenance of the truth in working memory is not a necessary prerequisite to lie generation. This has important implications for the legal system as the PSI rule makers may have gotten lucky by establishing a rule that fits with the neuroscience evidence. In short, our findings suggest that individuals, while capable of lying in extremely short time spans, lie differently when describing an event in the moment versus a past event in a way that makes cross examination that makes a third-party observer more effective in the moment and cross examination more effective for lies about past events.

CHAPTER 3

Working Memory Load During Lie Generation about Contemporaneous or Past Complex Stimuli

Introduction

The results from Chapter 2 suggest that individuals do not have to maintain a truthful representation of a to-be-lied about stimuli, contrary to the assumptions of most lie generation theories (Farah et al., 2014; Foerster et al., 2019). The results showed that individuals can switch between two cognitive strategies of lying: a slower, higher working memory load strategy and a faster, lower working memory load strategy. It also appeared, however, that individuals may need a delay in order to switch from the cognitively demanding to the less cognitively demanding strategy and the task only involved simplistic stimuli. It remains to be seen, therefore, how extrapolatable these findings are.

These findings also have real world implications with the Federal Rules of Evidence admitting normally inadmissible hearsay evidence when the witness makes a statement contemporaneously while viewing an event with the assumption that individuals do not have time to make up a lie. Our findings in the limited lab setting suggested that while the reasoning may be flawed, the rules functioning may fit with the cognitive and behavioral realities as people switched to the faster, less cognitively demanding lie strategy with a delay but did not in the moment. While our results from Chapter 2 cast doubt on a foundational principle of most lie generation theories and provides important insight for legal policy makers, it remains possible that while lie generation may not technically require the maintenance of a truthful representation to lie, this is an accurate enough assumption for any scenario experienced outside of a lab, and even most in lab.

The Information Manipulation Theory 2 is one of the few theories of lie generation that does not presuppose that lying is always more cognitively demanding and working memory intensive than truth-telling, but varies depending on the information activated in memory and the degrees of freedom in the problem-solving scenario (McCornack et al., 2014). Gamer et al. has also suggested that the consistent finding of increased cognitive load for lying compared to truth telling is actually due to the paradigms used rather than inherent to the process of lying (Gamer et al., 2012). Chapter 3 further tests the assertions of Gamer and the Information Manipulation Theory 2, explores how generalizable our findings from Chapter 2 are, increases our understanding of the cognitive processes inherent to lie generation, and further tests the assumptions that legal policy makers depend on in admitting or excluding evidence that could be the difference between an innocent man going to prison or letting a criminal go free.

Chapter 3 builds on Chapter 2 by employing a novel lie paradigm. In this paradigm, participants again lie contemporaneously or after a delay about a visual stimulus but about a far more complex visual stimuli, a three-color pie chart. This change allows us to probe several additional aspects of lie generation. First, Ganis et al. (2003) demonstrated that different types of lies engage different cognitive processes, including the difference between spontaneous and previously memorized lies and between independent and integrated into a scenario lies (Ganis, 2003). Integrated lies were lies that were coherent and internally consistent and would be probed with multiple questions where your answer for one question would constrain your possible answers to others. Independent lies were one-word responses to simple questions with no dependence on other answers. Previously memorized lies referred to lies the participant was allowed to form, memorize, and rehearse prior to questioning and spontaneous were referred to questions asked without any forewarning as to content and no chance to prepare a response (Ganis, 2003). The current paradigm allows us to test spontaneous-integrated lies, the type of lie most relevant to the PSI and untested by Ganis et al. (2003). Second, in many lie paradigms participants are instructed on which trials to lie and on which to be truthful. Here, participants are score motivated to lie rather than being explicitly instructed to do so on any given trial. Third, one of the biggest drawbacks of most lie paradigms, including the one used in Chapter 2 is that there is a lack of real deceit, an important aspect of lying in real-world situations (J. D. Greene & Paxton, 2009). The current paradigm where participants are "caught" and lose points more closely approximates the risks and costs of lying. The design of our lie paradigm also allows us to look at differences between lying and truth telling at two different time points, upon seeing the initial stimuli and upon questioning.

To test the differences in working memory and cognitive load we rely on one of the oldest and most well studied ERPs, the P300. While there are numerous theories about the P300, one of the oldest and most persistent is that it represents memory updating (Duncan-Johnson & Donchin, 1977). Participants compare the observed stimulus to their working memory template for the stimulus and if an attribute change has occurred, the P300 indexes the updating of the mental model (Donchin, 1981; Polich, 2012). Supporting this theory, an increased amplitude has also been tied to memory updating and encoding processes and is correlated with subsequent memory performance (Azizian & Polich, 2007; Polich, 2012). These processes primarily refer to what has now been subcategorized as the P3b, which has a more parietal-occipital topography than the sensory-related P3a (Folstein & Van Petten, 2008). Since the P3b seems to be sensitive, at least in part, to comparisons in working memory (Leuthold & Sommer, 1993; Polich, 2012; Sommer, Matt, & Leuthold, 1990), we would expect an increased P3b when individuals lie as they update their memory representation of the to-be-lied about stimulus. If, however, individuals are no longer holding the truthful representation of the stimulus in working memory, we would not expect an increased P3b since further schema updating would not be required. If an increased P3b is not observed, it can be inferred that the liars are not taxing their working memory more when lying compared to truth telling, providing further support that lying is not inherently working memory intensive but rather dependent on specific demands of the study paradigm.

Some studies, however, have previously reported a decreased P3b for lying compared to truth-telling (Hu et al., 2011; Sai, Wu, Hu, & Fu, 2018). These reports were limited to experiments where the participant was trying to mislead a confederate on all trials or when instructed to always be deceptive. Hu et al. found that this reduced P3b for lying disappeared when participants were told to monitor their responses and attempt to lie on about 50% of trials and, while not reported, visually appear to be larger.

It is important to note that this is distinct from the common use of the P300 in the Concealed Information or Guilty Knowledge Test in which the P300 is believed to index conscious recollection of information, and so can be used to detect information only a guilty suspect would know (Hu, Bergström, Bodenhausen, & Rosenfeld, 2015). Importantly in all conditions the only visual stimulus the participants are presented with is the truthful stimulus and the stimulus represented by their lies is never shown to be subsequently recognized.

Finally, I will also measure the amplitude of the parietal N1 component during lie generation. Previous research has found an increased N1 for lying compared to truth-telling (Hu et al., 2011). The researchers attributed the increase to enhanced attention allocation to the to-be-lied-about stimuli due to the subsequent need for increased cognitive processing for stimuli evaluation and response monitoring for lie generation compared to truth telling (Hu et al., 2011). Accordingly, if individuals are switching to a less cognitively demanding lie generation technique following a delay, we would expect to see an increased N1 for deceitful compared to truthful responses in the contemporaneous condition but no difference or a reduced difference for responses following a delay. Alternatively, we would expect to see no change in the difference between lying and truth-telling between the delay conditions if no cognitive strategy switch is occurring. The N1 has also been associated with perceptual predictions, with violations resulting in increased amplitude (Johnston et al., 2017).

Method

Participants

All participants gave written informed consent according to procedures approved by the Vanderbilt University Institutional Review Board. All volunteers self-reported that they were neurologically normal, had normal or corrected-to-normal visual acuity, and were not color-blind. Data from 7 participants with fewer than 200 artifact free trials were excluded from analysis, leaving 21 participants in the sample.

Stimuli

The stimuli were generated and presented in MATLAB using the Psychophysics Toolbox (Brainard, 1997; Pelli, 1997). Participants were seated approximated 60 cm from the CRT monitor. Stimuli were presented in the center of the screen and were a pie chart made up of three colors chosen from four (Yxy values: red, x = 0.594, y = 0.339, 9.75 cd/m^2; black, x = 0.271, y = 0.365, 0.89 cd/m^2; blue, x = 0.145, y = 0.075, 5.46 cd/m^2; orange, x = 0.442, y = 0.467, 37.4 cd/m^2). Each pie chart subtended 4.77 × 2.39° degrees in visual angle from fixation and were presented on a grey background (x = 0.273, y = 0.311, 18.3 cd/m^2). The text subtended 3.34° below fixation and the question prompt subtended 4.77° below fixation and was written in the color value of the color being asked about.

Task

The pie chart task was designed to elicit several key aspects of deception. First, participants were score motivated to lie but chose on which trials to be truthful and which to be deceitful. Second, there was an element of actual deceit and a risk of loss due to a "caught" condition in which even if the participant responded correctly with a deceitful response they could lose ten points if they were caught. The catch rate was adjusted at the end of each block based on their behavior such that the expected value of truth-telling and lying was always the same and to attempt to get the participants to lie on about 50% of the trials. Third, participants had to integrate their lie into a broader scenario since they always had to respond to a question about all three colors, not just their color of interest, and would lose 10 points if the percentages did not add to 100%.

Specifically, at the start of each block participants were assigned a target color. They could then gain points by either reporting the percent of that color truthfully or deceitfully and were told to try to maximize their score. At the start of each trial participants were shown a fixation point in the color of their target color. They would then press a button to start a trial at which point a three-color pie chart was displayed along with text stating the actual percent actually occupied by each color. Depending on condition after either 500 or 3000 ms delay participants would be prompted to report the percent of one of the colors in the pie chart. Following a response, the answer prompt for the next color would appear until all three colors had been prompted. The participants would then be shown the result of the trial. If the participant told the truth about their target color, they were awarded 3 points, if they lied to increase it by 5% they gained 5 points, if they lied to increase it by 10% they were awarded 10 points. If, however, they made an error, defined as either failing to respond to one of the three questions, failing to have all three answers sum to 100%, or eliminating one of the colors from the pie chart, the participant would lose ten points. Additionally, on a certain percent of trials the participant would be caught on lie trials. The catch rate was adjusted after each block based on the participants behavior such that the expected value of truth telling and lying was always equal.

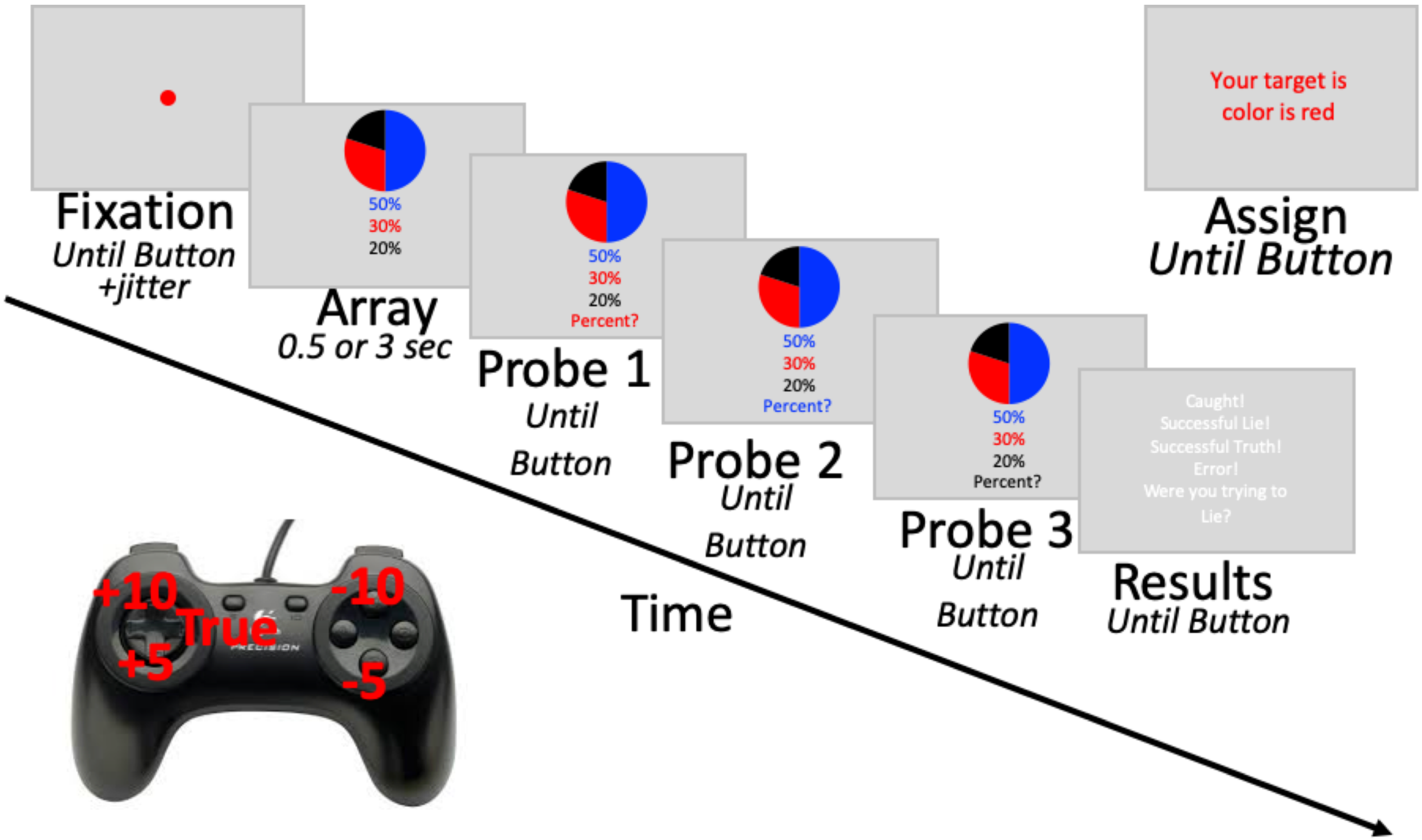

Figure 6. Stimuli timing and presentation. At the start of each block participants were assigned a target color. They could then gain points by either reporting the percent of that color truthfully or deceitfully and were told to try to maximize their score. At the start of each trial participants were shown a fixation point in the color of their target color. They would then press a button to start a trial at which point, after a 700 to 1100ms jitter, a three-color pie chart was displayed along with text stating the actual percent actually occupied by each color. Depending on condition after either 500 or 3000 ms delay participants would be prompted to report the percent of one of the colors in the pie chart. Following a response, the question prompt for the next color would appear until all three colors had been prompted. The participants would then be shown the result of the trial. If the participant told the truth about their target color they were awarded 3 points, if they lied to increase it by 5% they gained 5 points, if they lied to increase it by 10% they were awarded 10 points. If, however, they made an error, defined as either failing to respond to one of the three questions, failing to have all three answers sum to 100%, or eliminating one of the colors from the pie chart, the participant would lose ten points. Additionally, on a certain percent of trials the participant would be caught on lie trials. The catch rate was adjusted after each block based on the participants behavior such that the expected value of truth telling and lying was always equal.

EEG Data Acquisition & Analysis

The EEG data were recorded using a right-mastoid reference and were referenced off-line to the average of the left and right mastoids. We used the international 10-20 electrode sites (Fz, Cz, Pz, F3, F4, C3, C4, P3, P4, PO3, PO4, O1, O2, T3, T4, T5, and T6) and a pair of custom sites, OL (halfway between O1 and T5 and OR (halfway between O2 and T6). Eye movements were monitored using electrodes placed 1 cm lateral to the external canthi for horizontal movement and an electrode placed beneath the right eye for blinks and vertical eye movements. The signals were amplified with a gain of 20,000, band-pass filtered from 0.01 to 100 Hz, and digitized at 250 Hz. Trials accompanied by horizontal eye movements (>30 μV mean threshold across observers) or eye blinks (>75 μV mean threshold across observers) were rejected before further analyses. Participants with fewer than 200 artifact free trials in any condition were excluded from further analysis.

ERP Analysis

P3b

To examine the P3b during lie generation, we time-locked waveforms to two separate stimuli in the lie generation process, both the initial stimuli onset and to each of the three question prompts (Figure 6) and examined the ERPs recorded from 0 to 1000ms following the onset of each question prompt. These ERP epochs were baseline corrected to the mean amplitude -200 to 0 ms. The P3b was calculated for electrode sites Pz, P3, P4, P03, P04, 01, 02, OL, and OR from 300 to 700ms from question prompt onset (R. U. Johnson, Kreiter, Russo, &

Zhu, 1998). Statistics were performed in JASP on the baseline-corrected but unfiltered data (JASP, 2018). For visualization, all figures display data passed through a 30Hz low pass filter.

N1

To examine the N1 during lie generation, we time-locked waveforms to two separate stimuli in the lie generation process, both the initial stimuli onset and to each of the three question prompts (Figure 6) and examined the ERPs recorded from 0 to 1000ms following the onset of each question prompt. These ERP epochs were baseline corrected to the mean amplitude -200 to 0 ms. The N1 was calculated for electrode sites Pz, P3, P4, P03, P04, 01, 02, OL, OR from 120 to 220ms from question prompt onset (Johnston et al., 2017).

Results

Behavior

Reaction Time

Caught and successful lies were pooled for analysis since the participant's responses did not vary between the two and they would not know if they would be caught at the time of their response. As expected, and consistent with the literature, there was a main effect of response (lie, true, error) ($p < 0.001$, $F(2,40) = 80.031$) with participants slowest to respond when making an error, followed by lying, followed by truth-telling (Figure 7). There was also a trend towards a significant main effect of delay with individuals being slower to respond in the contemporaneous condition compared to following a delay ($p = 0.057$, $F(1,20) = 4.087$).

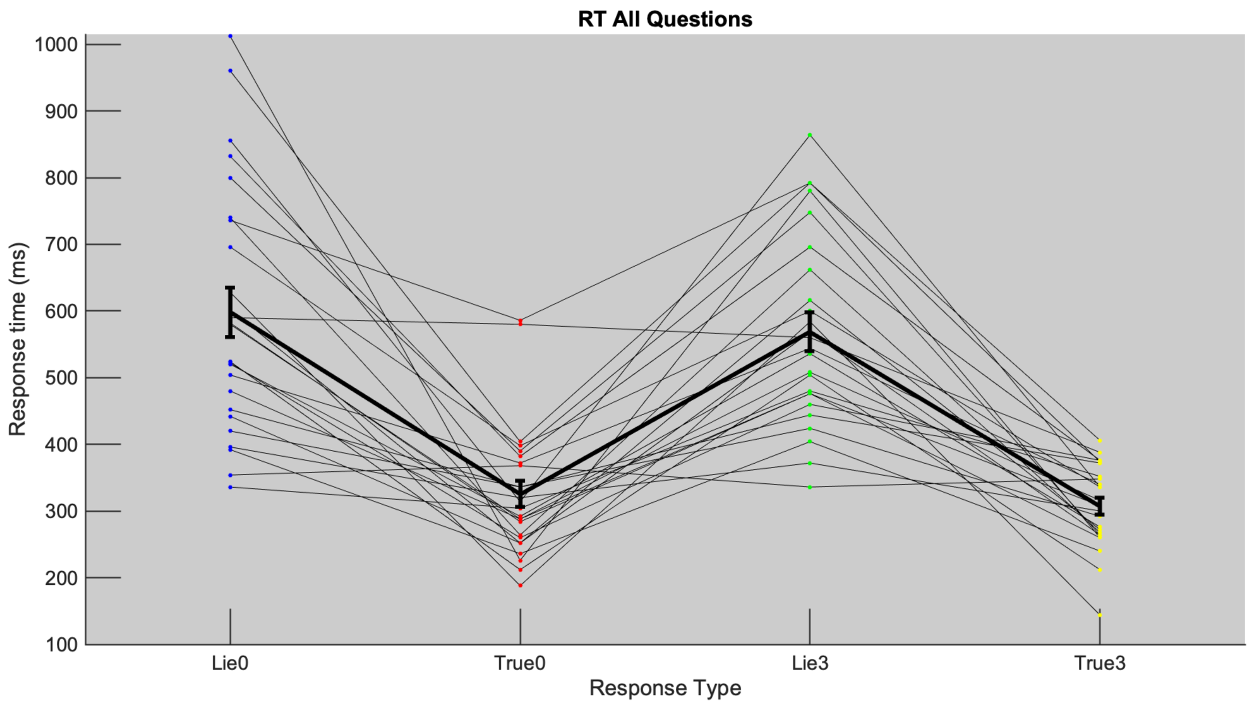

Figure 7. Median Reaction Time Across Conditions. There was a significant main effect of response (lie, true, error) with participants slowest to respond when making an error, followed by lying, followed by truth-telling. There was also a trend towards a significant main effect of delay with individuals being slower to respond in the contemporaneous condition compared to following a delay.

Response Types Across Conditions

On average, participants in the contemporaneous condition lied 44.23% ± 2.6% SEM, told the truth 42.8% ± 2.72% SEM, and made an error 12.97% ± 1.71% SEM. In the delay condition, on average participants lied 53.66% ± 2.17% SEM, told the truth 37.96% ± 2.23% SEM, and made an error 8.38% ± 0.91% SEM (Figure 8). Paired two-tailed independent t-tests found that participants made significantly more errors ($t(20) = 3.896$, $p < 0.001$) and told the truth more ($t(20) = 2.771$, $p = 0.012$) in the contemporaneous condition and lied significantly more in the delay condition ($t(20) = -5.820$, p =< 0.001).

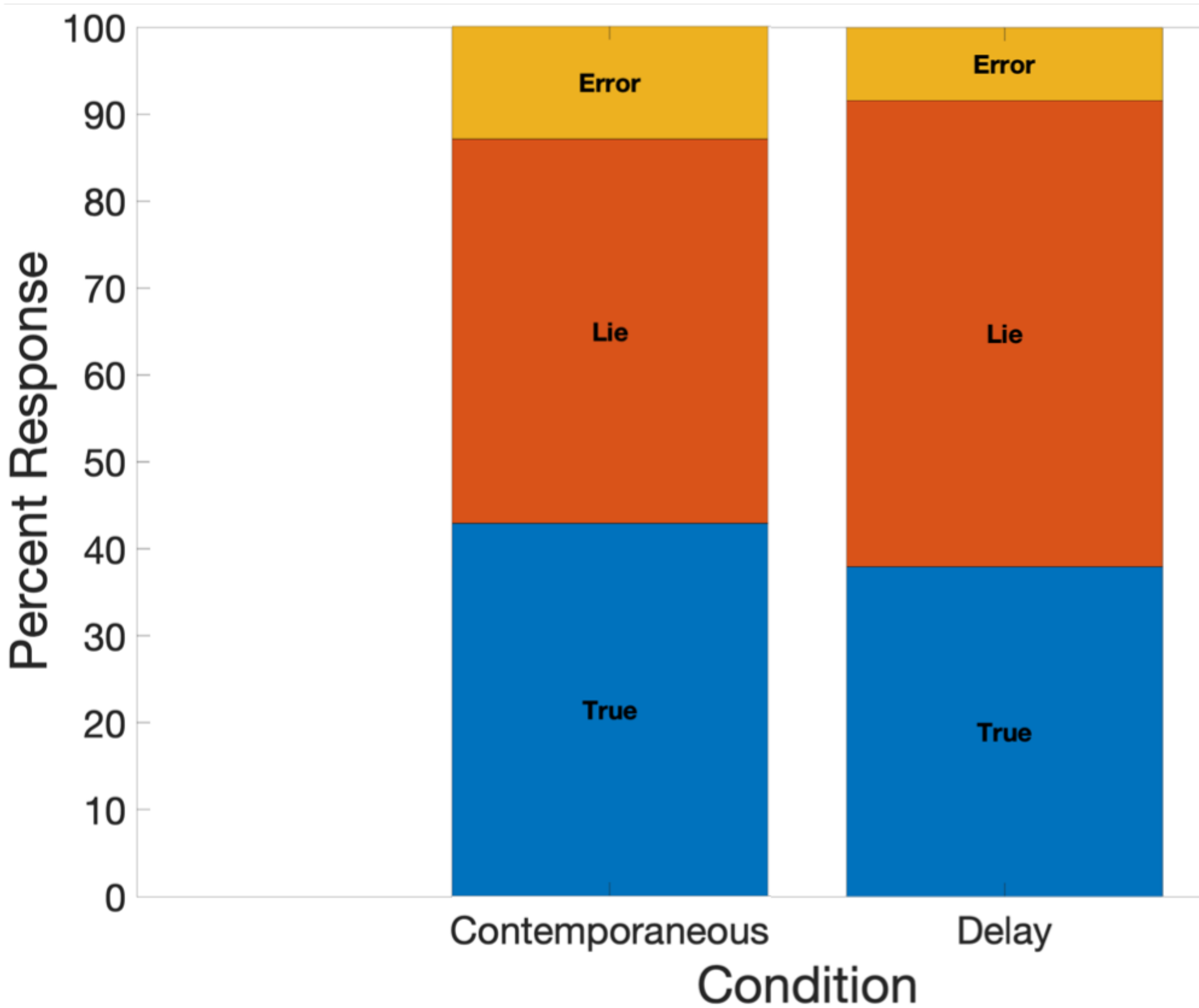

Figure 8. Response Types Across Conditions. Participants made significantly more errors and told the truth significantly more in the contemporaneous condition and lied significantly more in the delay condition.

ERPs

P3b Pie Chart Locked

Figure 9 shows the pattern of results we observed across parietal channels, where the P3b is maximal. As shown in Figure 11, a repeated measures two-way ANOVA revealed a significant main effect of response with larger mean amplitudes for lying compared to truth-telling suggesting increased memory context updating in both delay conditions ($p = 0.01$, $F(1,20) = 8.211$). There was no significant effect of delay ($p = 0.878$, $F(1,20) = 0.024$).

Scalp topography also varied as shown by a main effect of electrode ($p = 0.011$, $F(2.583,51.655) = 4.42$), after performing Greenhouse-Geisser correction for a violation of sphericity (epsilon < 0.75), and significant interactions between electrode and response ($p = 0.046$, $F(2.365,47.308) = 3.115$) and a significant three-way interaction between electrode, delay, response ($p = 0.048$, $F(2.472,49.440) = 3.013$).

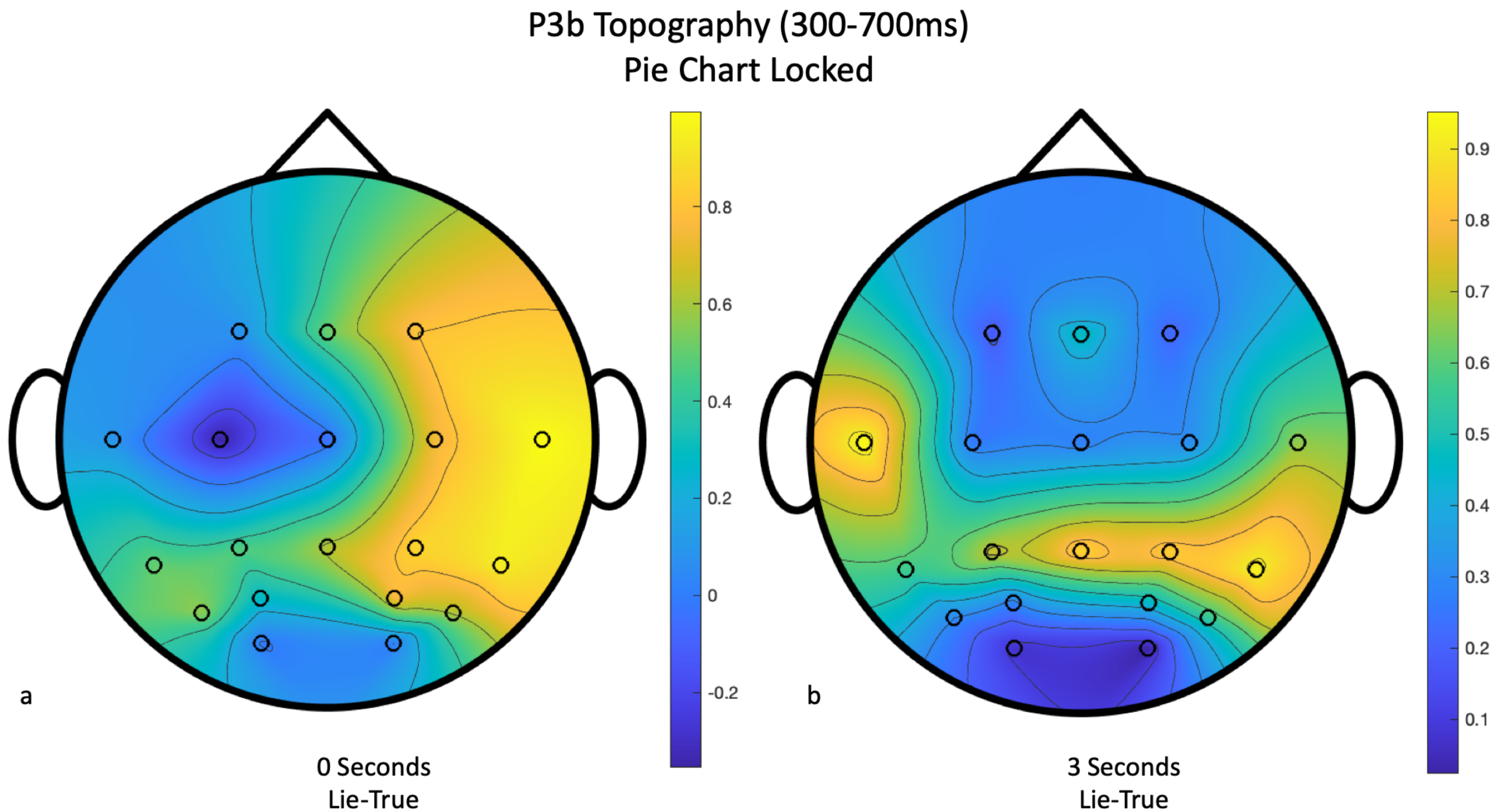

Figure 9. Pie Chart Locked P3b Electrode Topography. The scalp topography for the EEG data during the P3b time window (300-700ms) post Pie Chart onset. The bottom left, (a) displays the scalp topography for the lie minus truth activity for the contemporaneous condition. The bottom right, (b) displays the scalp topography for the lie minus truth activity for the delay condition. There was a significant main effect of electrode and interactions between electrode and response and electrode, delay, and response, as shown by the topographic plots.

N1 Pie Chart Locked

Figure 10 shows the pattern of results we observed across parietal channels, where the N1 is maximal. As shown in Figure 11, a repeated measures two-way ANOVA found no significant main effects of delay ($p = 0.637$, $F(1,20) = 0.230$) or response ($p = 0.339$, $F(1,20) = 0.959$) suggesting no difference in attention or arousal, as indexed by the N1, between lying and truth-telling at this stage of the lie generation process. Scalp topography did vary as shown by a significant main effect of electrode ($p =0.005$, $F(2.681,53.62) = 5.101$), after performing Greenhouse-Geisser correction for a violation of sphericity (epsilon < 0.75), a significant two-way interaction between electrode and delay ($p < 0.001$, $F(2.852,57.044) = 11.952$), and a significant three-way interaction between electrode, delay, and response ($p = 0.012$, $F(2.029,40.58) = 4.961$).

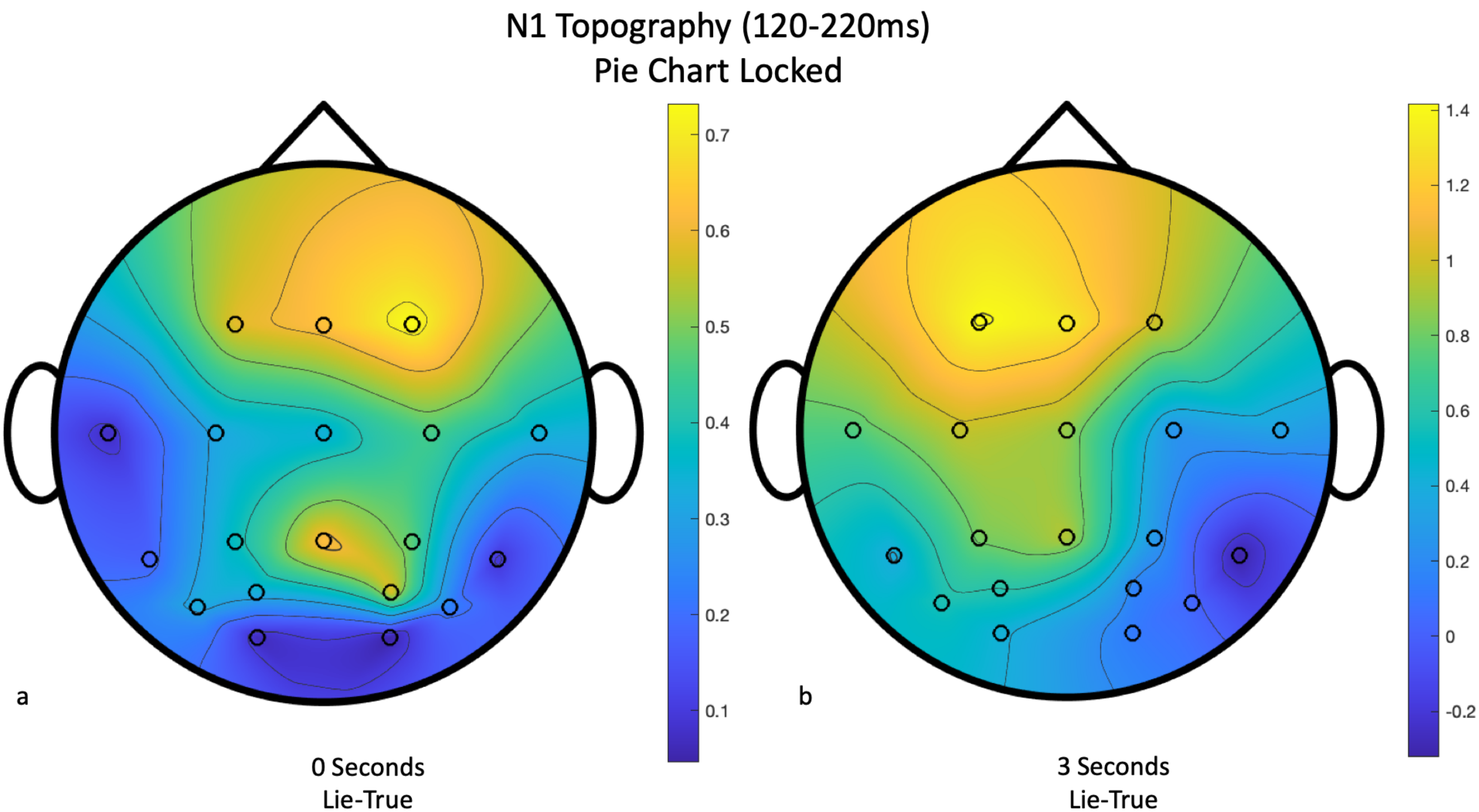

Figure 10. Pie Chart Locked N1 Electrode Topography. The scalp topography for the EEG data during the N1 time window (120-220ms) post Pie Chart onset. The bottom left, (a) displays the scalp topography for the lie minus truth activity for the contemporaneous condition. The bottom right, (b) displays the scalp topography for the lie minus truth activity for the delay condition. There was a significant main effect of electrode and interactions between electrode and delay, and electrode, delay, and response, as shown by the topographic plots.

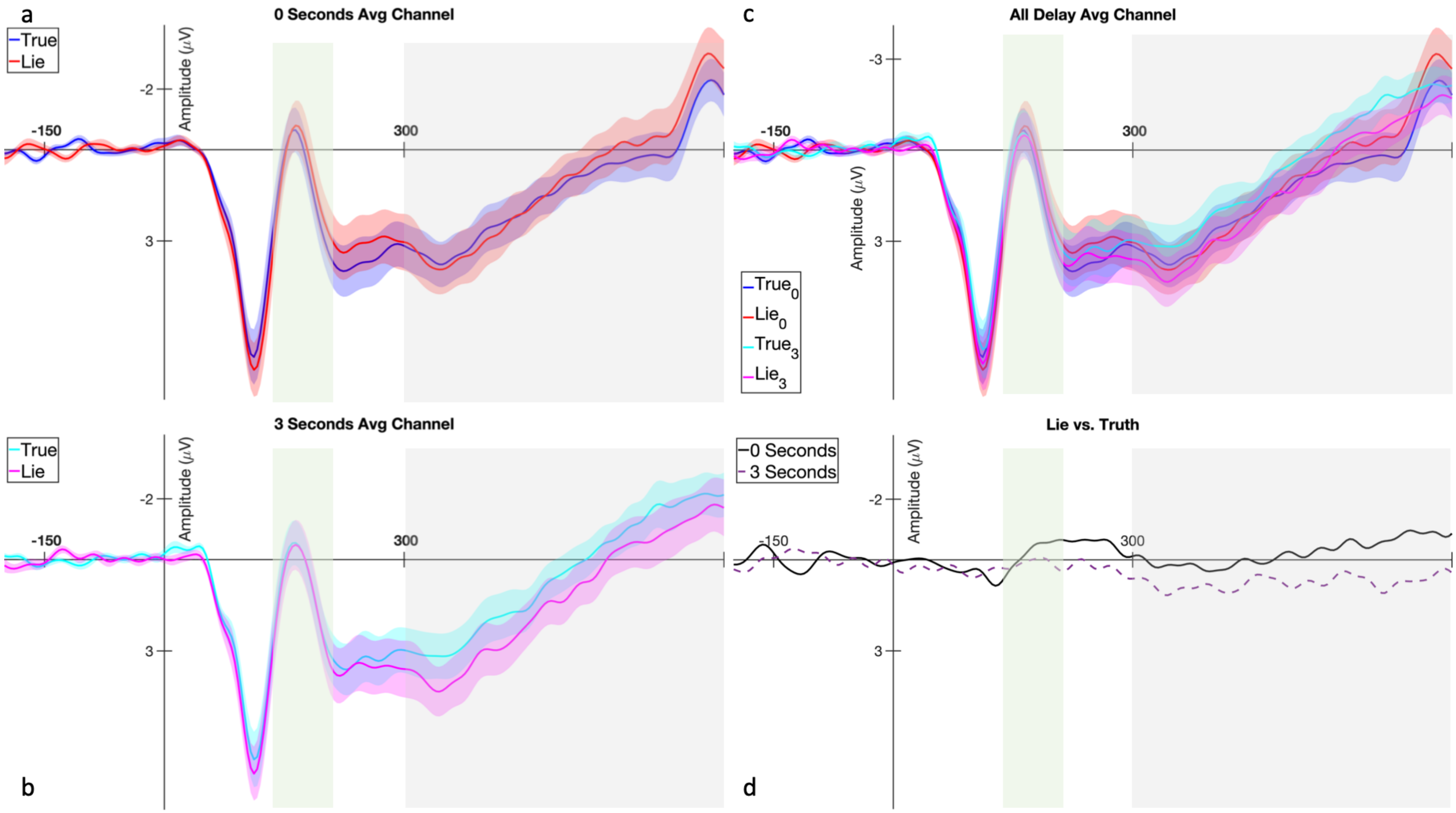

Figure 11. ERP Data Across Conditions. The EEG data from -200 to 700ms, time locked to pie chart presentation, is presented with the timeframe for the P3b outlined in gray and for the N1 outlined in green. The two graphs on the left show the EEG for truth telling and lying in (a) the contemporaneous condition and (b) the delay condition. The top right, (c) shows the EEG for truth telling and lying in all time conditions. The bottom right, (d) displays the difference wave for lying minus truthful in the 0.5 and 3 second conditions. The P3b was found to be significantly increased for lying compared to truth telling in both the delay and contemporaneous condition. There were no significant effects of response or delay on N1 mean amplitude. The shaded area around traces represents standard error.

P3b Question Locked

Figure 12 shows the pattern of results we observed across parietal channels, where the P3b is maximal. As shown in Figure 14, a repeated measures two-way ANOVA revealed a significant main effect of delay with significantly larger mean amplitudes following a delay compared to contemporaneous ($p < 0.001$, $F(1,20) = 81.770$) and a significant main effect of response with larger mean amplitudes for lying compared to truth-telling response ($p < 0.001$, $F(1,20) = 99.917$). There was also a significant interaction between delay and response with P3b increasing more for lying compared to truth-telling for contemporaneous responses compared to delayed responses ($p = 0.002$, $F(1,20) = 13.446$).

Scalp topography also varied as shown by a main effect of electrode ($p < 0.001$, $F(1.506,30.130) = 35.627$), after performing Greenhouse-Geisser correction for a violation of sphericity (epsilon < 0.75), and significant interactions between electrode and delay ($p = 0.003$, $F(1.888,37.755) = 6.990$), electrode and response ($p < 0.001$, $F(2.360,47.201) = 17.863$), delay and response, and a significant three way interaction between electrode, delay, response ($p < 0.001$, $F(2.738,54.755) = 4.253$).

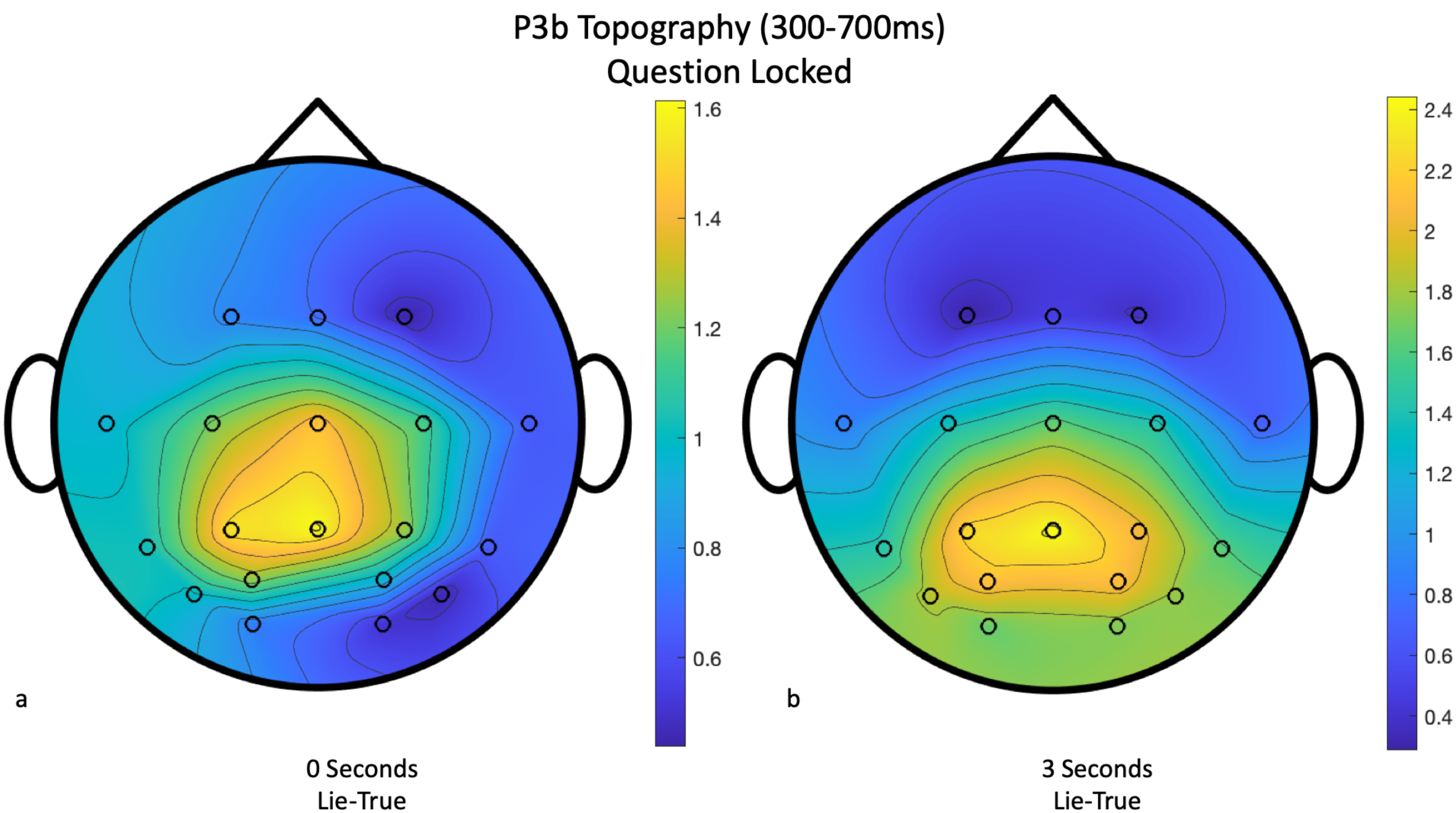

Figure 12. P3b Electrode Topography. The scalp topography for the EEG data during the P3b time window (300-700ms) post question. The bottom left, (a) displays the scalp topography for the lie minus truth activity for the contemporaneous condition. The bottom right, (b) displays the scalp topography for the lie minus truth activity for the delay condition. There was a significant main effect of electrode and significant interactions between electrode and delay, electrode and response, and a significant three-way interaction between electrode, delay, response.

N1 Question Locked

Figure 13 shows the pattern of results we observed across parietal channels, where the N1 is maximal. As shown in Figure 14, a repeated measures two-way ANOVA found a significant main effect of delay ($p = 0.023$, $F(1,20) = 6.091$), with larger N1s in the contemporaneous condition than in the delay condition, and for response ($p = 0.002$, $F(1,20) = 13.355$) with larger N1s for deceitful responses than for truthful response. Scalp topography also varied as shown by a significant main effect of electrode ($p < 0.001$, $F(2.002,40.033) = 9.626$), after performing Greenhouse-Geisser correction for a violation of sphericity (epsilon < 0.75) and a significant two-way interaction between electrode and delay ($p < 0.001$, $F(2.117,42.334) = 8.413$).

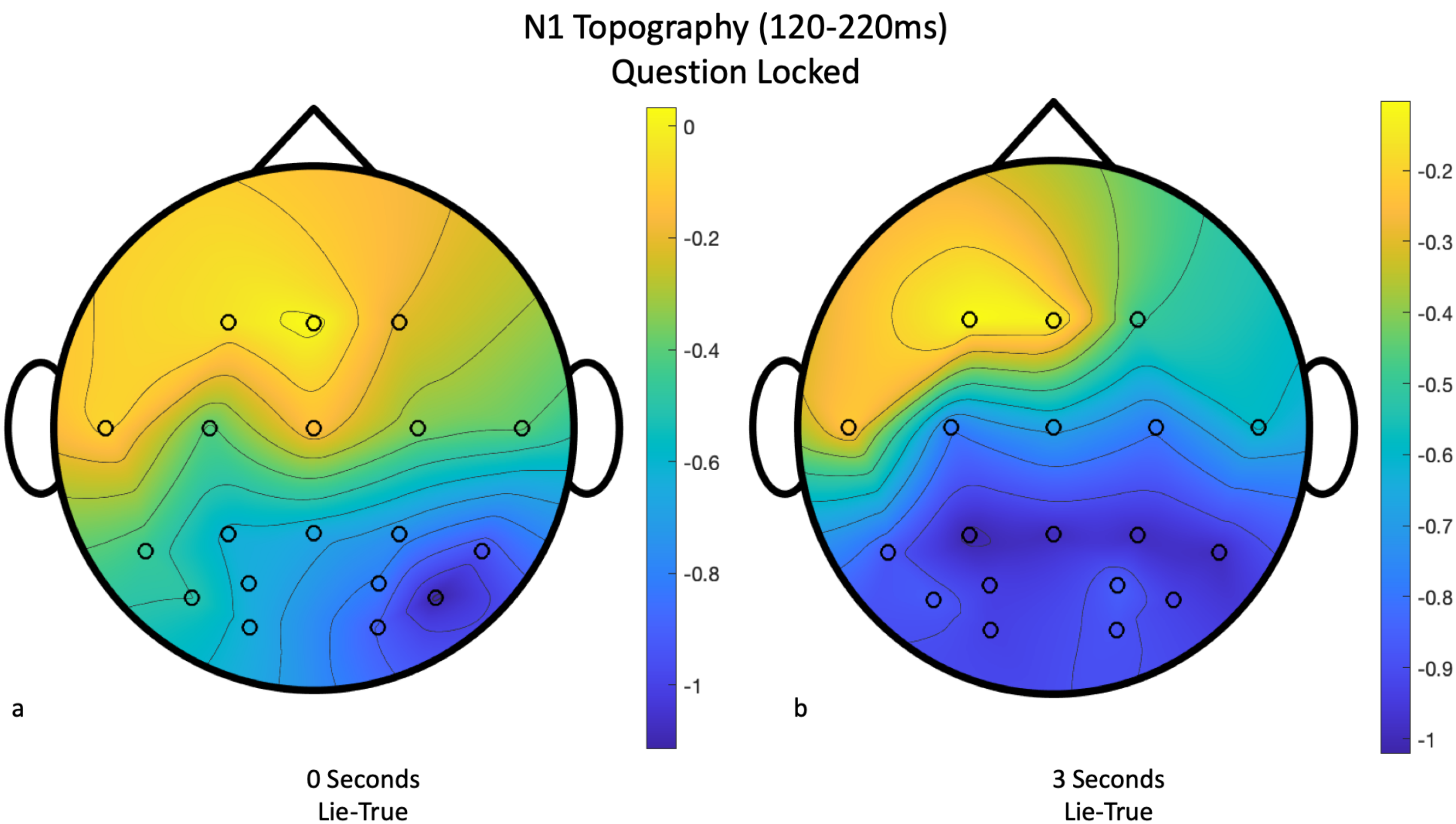

Figure 13. N1 Electrode Topography. The scalp topography for the EEG data during the N1 time window (120-220ms) post question. The bottom left, (a) displays the scalp topography for the lie minus truth activity for the contemporaneous condition. The bottom right, (b) displays the scalp topography for the lie minus truth activity for the delay condition. There was a significant main effect of electrode and a significant two-way interaction between electrode and delay.

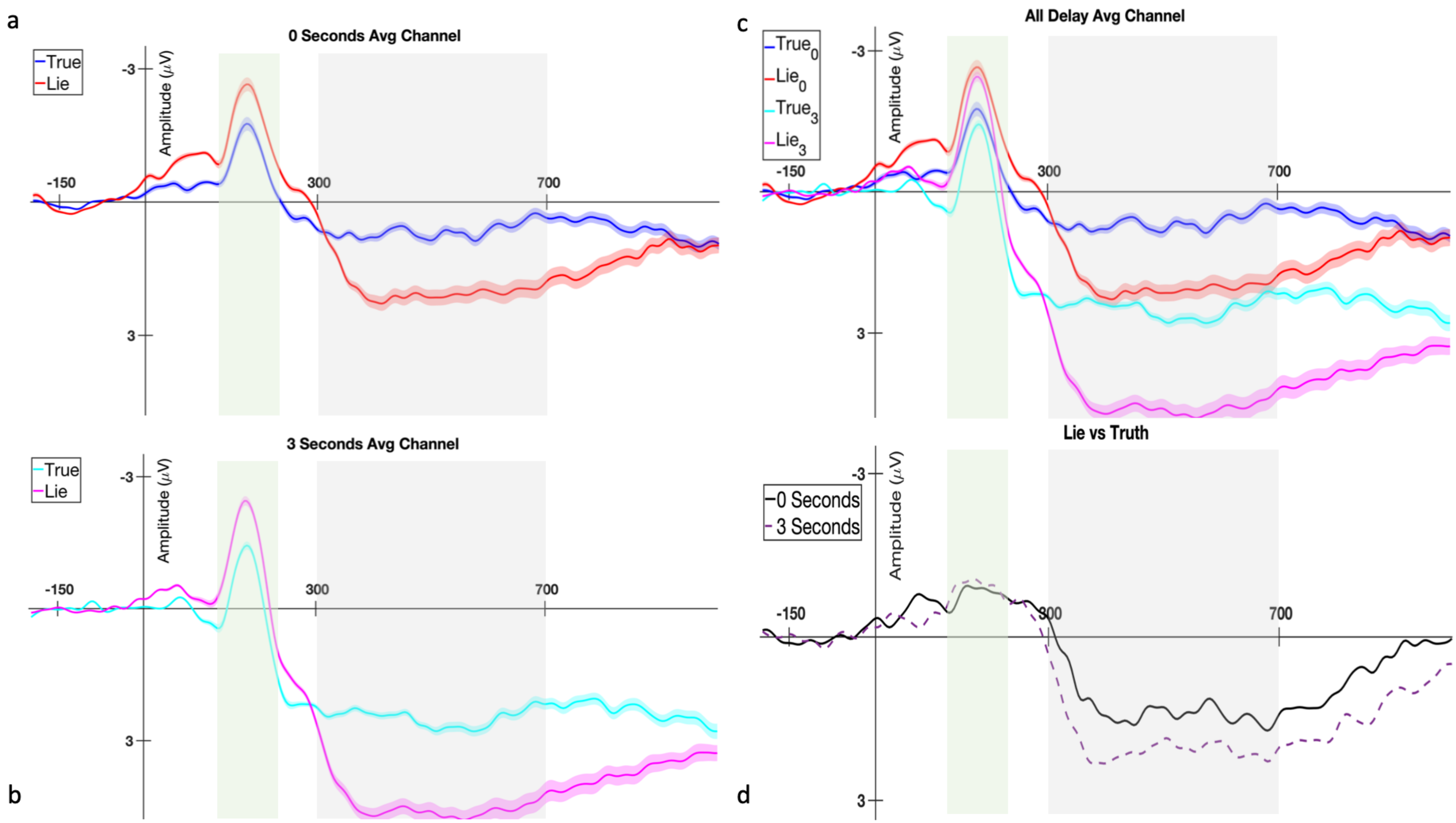

Figure 14. ERP Data Across Conditions. The EEG data from -200 to 700ms, time locked to question presentation, is presented with the timeframe for the P3b outlined in gray and for the N1 outlined in green. The two graphs on the left show the EEG for truth telling and lying in (a) the contemporaneous condition and (b) the delay condition. The top right (c) shows the EEG for truth telling and lying in all time conditions. The bottom right, (d) displays the difference wave for lying minus truthful in the 0.5 and 3 second conditions. The P3b was found to be significantly increased for lying compared to truth telling and for the delay condition compared to the contemporaneous condition. There was also a significant interaction between response and delay with a larger increase for lying compared to truth telling in the delay condition. The N1 was found to be significantly increased for lying compared to truth telling and in the contemporaneous condition compared to the delay condition. The shaded area around traces represents standard error.

Discussion

Our results suggest that individuals likely engage in increased memory updating when lying both contemporaneously and after a delay and were not able to lessen the behavioral cost of lying when given a delay, as indexed by the increased P3b upon question onset when lying in both delay conditions and the lack of an interaction between delay and response in reaction time. This suggests that our findings from Chapter 2, when individuals switched to a less working memory intensive cognitive lie generation strategy after a delay, may be limited to simple instances in which people lie about forced choice answers that do not need to fit into a scenario (e.g., yes versus no). The current paradigm added several layers of complexity which could account for the difference: a) strategic monitoring of their responses since they selected on which trials to lie; b) emotional regulation since there was a cost to being caught; or c) broader context representation since they had to integrate their lie into the scenario such that all three of their answers added to 100%. Given that even when simply lying about the color of a square, when directed to, and with no cost of an error, participants still needed a delay to engage this lower working memory load strategy, it is plausible that any one of or all of these additional cognitive demands made the switch impossible. Alternatively, it could be that the increased complexity necessitates a longer delay to facilitate the switch, beyond the 3000ms allowed by our paradigm. If so, while Chapter 2 suggested that maintenance of the truth is not an absolute prerequisite for lie generation as most models assume, our current results suggest that this step occurs in all but the most simplistic of scenarios and fails to provide additional evidence for the Information Manipulation Theory 2 or Gamer et al. over other models of lie generation.

The increased posterior N1 for lying compared to truth-telling in both delay conditions in response to question onset also suggests that individuals did not switch to a lower working memory load lie strategy after a delay. The posterior N1 is associated with increased attention allocation presumed to be necessary for downstream cognitive operations. This increased N1 is therefore suggestive of increased downstream stimulus evaluation and response monitoring when lying in both delay conditions. That the increased N1 is not found in response to the pie chart onset suggests not only that the decision to lie does not occur immediately upon stimulus onset but also that increased attention in preparation to lie does not occur until questioning. It is also possible, however, that the response mapping could explain this difference in N1 amplitudes since participants had to press multiple buttons to lie but only one button to tell the truth. Researchers have hypothesized that the N1 reflects a generalized discrimination process, as the N1 increases when participants must make a choice response compared to a present/absent response for the same stimuli but no difference is seen between present/absent evaluations between simple and complex stimuli (Vogel & Luck, 2000). Truth telling in our paradigm could be equivalent to a present/absent evaluation (lie/do not lie) and lying could be a downstream second decision requiring a decision of which button to press. Future experiments should require participants to use a number wheel or keyboard to enter the percent for each color to eliminate this potential confound.

Unlike the differences in the N1, the difference between lying and truth telling for the P3b emerge as early as pie chart presentation, suggesting that the decision to lie has occurred prior to questioning and participants are already updating their memory representations of the pie chart in preparation for lying, regardless of whether they are in a contemporaneous or delay block condition. The main effect of delay in the P3b, however, has yet to emerge. Examination of the full trial EEG suggests that the later significant difference in the P3b between delay conditions may be due to a sustained negativity for lying in the delay condition throughout the delay period, possibly suggesting increased working memory maintenance throughout the trial.

The P3b, while sensitive to comparisons in working memory (Leuthold & Sommer, 1993; Polich, 2012; Sommer et al., 1990), is not as clean of an index of working memory load as the CDA, and so several alternative explanations remain. For example, even though we see an increased P3b for lying in both conditions, there is a significant interaction with the difference being larger after a delay. The P3b has been found to decrease as working memory load increases (Kok, 2001; Polich, 2012), suggesting that while memory updating is required in both scenarios, the larger P3b in the delay condition may actually be due to the dropping of the truthful representation from working memory, reducing working memory load, and thereby increasing the P3b. Additionally, the P3b in the delay condition could be a result of the continued display of the truthful pie chart on the screen. In other words, even if a truthful template is no longer being maintained in working memory, the continued visual display could cause a P3b in response to comparing the visual display to the maintained deceitful representation. Future studies should employ a paradigm that updates the displayed pie chart to match the deceitful responses to remove this possibility.

One other possible explanation for both the increased P3b and N1 is heightened arousal for lying compared to truth-telling, a common target of lie detection (Palmatier & Rovner, 2015). The arousal for lying would also be greater in this paradigm compared to in the

CDA paradigm as participants can now be caught and lose points. Previous research has found the N1 (Sibley, Mochizuki, Frank, & McIlroy, 2010) and P3b to increase in response to general arousal (Kang, Williams, Hermens, & Gordon, 2005). Other researchers, however, have found no difference in N1 amplitude based on arousal once other factors have been controlled for (Vogel & Luck, 2000). It is possible that this increased arousal is masking underlying differences and increases the importance of the observed interaction between response and delay in the P3b amplitude.

Conclusion

Our results suggest that lying about complex stimuli both contemporaneously and after a delay requires increased memory updating and attention allocation compared to truth-telling and that the attention allocation only occurs in response to questioning while the memory updating occurs in response to the initial presentation of the to-be-lied about stimuli, even when participants know they will have a delay. This contrasts with earlier research suggesting that individuals switch to a lower working memory load cognitive lie strategy when given a delay. These findings suggest that this switch either cannot happen in more complex tasks or requires more time than was allotted in our paradigm.

Our results, however, cannot rule out that a switch to a lower working memory load lie strategy did occur in the delay condition. Taken together, the interaction in the P3b amplitude locked to question onset between lying and delay, with a larger amplitude difference for lies compared to truths after a delay, and the increased amplitude in the N1 for the contemporaneous condition, provides some support for the proposition that lying after a delay is less cognitively demanding than lying in the moment. This reduced cognitive load could be due to a reduced working memory load following a delay caused by the dropping of the truthful representation of the to-be-lied about stimulus, as suggested by the reduced amplitude of the P3b for contemporaneous lies, which is associated with increased memory load. The P3b for lying in the delay condition could also be due to comparing a now deceitful working memory template to the still accurate on screen stimuli, necessitating memory updating. Further research is needed to test these hypotheses.

CHAPTER 4

General Conclusions

The evidentiary rules are essential to promoting efficiency, legitimacy, accuracy, and the overall policy goals of the justice system. Their success in promoting these goals, however, often hinges on critical, but frequently untested, psychological assumptions about how people produce and process information. The hearsay rules are no exception, and both the rule and its exceptions were crafted with these policy goals in mind and based on assumptions about how people think and behave.

Until recently, a plausible excuse for not testing many of these assumptions was the simple fact that they could not be tested. My dissertation work provides an example of how carefully designed neuroscience experiments can both provide additional information directly relevant to legal policy makers and advance our scientific understanding of important cognitive processes. The results of the experiments conducted throughout my dissertation contributes to basic cognitive models of lie generation by suggesting that maintaining multiple representations of a to-be-lied about stimulus is not a necessary prerequisite to lie generation, as most models assume, and provides valuable information to legal policy makers by suggesting that while the core assumption of the PSI may be wrong, its functioning may still be well suited for the neurologic and behavior realities of lying in the moment or about a past event, at least for true contemporaneity.

Specifically, our findings from Chapter 2 suggest that when lying about contemporaneous events, individuals appear to rely primarily on a slower, more working memory intensive lie cognitive process that may result in better memory of the event, but more behavioral tells detectable by a third party observer. When lying after a delay, however, individuals seem to switch to a faster, less memory intensive cognitive lie strategy that may reduce their behavioral tells but potentially at a cost to their overall memory of the surrounding scene such that skilled cross examination may reveal the lie. The existence of this second lower working memory load strategy contributes to the basic science literature on lie generation.

In Chapter 3 we built on the results from Chapter 2 by increasing ecological validity through more complex stimuli and task decisions. Specifically, individuals were presented with more complex stimuli, chose on which trials to lie, had to integrate their lies into a coherent scenario, and had a risk of being caught with a resulting point penalty. The results are more ambiguous than our findings from Chapter 2 but suggest that when lying about more complex stimuli lying still requires increased working memory compared to truth-telling even after a delay. The results, however, do not rule out the possibility that while lying is more cognitively demanding in both conditions, the working memory load is lighter following a delay, as shown by the main effect of delay and the interaction between response and delay with a reduced difference between lying and truth telling in the contemporaneous condition, possibly due to increased memory load or the comparison of deceitful working memory representation to a still accurate on screen representation. This finding suggests that either switching to a lower working memory load lie strategy is not possible with complex stimuli and situations, may require more time, or that other factors may lessen some of the benefits and in many cases mask the switch to this lower working memory load strategy.

Future research needs to reduce the ambiguity of our findings from Chapter 3. This could be done either by using more direct measures of working memory load for complex non-lateralized stimuli or through a follow-up in which the pie-chart adjusts to the responses of the participant, removing one of the confounds that added ambiguity to our results in the inherent clash between the truthful pie-chart on the screen and the given deceitful response. Additionally, while we hypothesize that it is the dropping of the truthful representation that accounts for the drop in working memory load observed in Chapter 2, future experiments should directly assess this hypothesis by probing memory for the truthful representation following the telling of a delayed lie. This is especially true to advance this work's contribution to the lie generation field. Our findings suggest that the Information Manipulation Theory 2, while in the minority, is correct in assuming that lying does not require a higher working memory load and the maintenance of the truthful representation, but that this depends on the specific cognitive demands of the task.

We also believe that the paradigm developed in Chapter 3 provides a valuable new tool to lie generation researchers. This paradigm improves upon many of the traditional paradigms by moving beyond yes/no and pre-instructed lies, forcing participants to integrate their lies into a coherent scenario while still giving experimenters sufficient control over the response space, and providing two separate time windows into the lie generation process by divorcing the presentation of the to-be-lied about stimuli and questioning. Furthermore, by using a score motivated system that equalizes the expected value of lying and truth-telling, experimenters can get a roughly equal response rate while still allowing the participants to choose on which trials to lie and with their goal being to maximize points, not artificially equalize their response rates. Lastly, it adds an element of risk to being caught, an important element of lie generation often left out of paradigms. The paradigm achieves these elements while still allowing EEG recordings throughout the process, unlike some paradigms that capture these elements but only allow for EEG recording during one aspect of the task, such as with the mock-crime concealed information task.

Our current results suggest that in simple situations requiring observers to lie within a second of an observation, the assumptions underlying PSI are accurate. However, this difference quickly disappears following even short delays of a few seconds or increases in task complexity. To advance the legal contribution of this research, future studies should apply a similar approach but utilize more legally relevant real-world scenarios involving more complex lies. Under my NIJ training grant we are currently conducting one such follow up in which observers narrate movies of ongoing crimes. Observers will narrate each movie either deceitfully or truthfully in real time or following a delay. We will also play these narrations to third party listeners, which will allow us to assess of the remaining untested assumption of the PSI, that third parties are better able to detect lies about contemporaneous events. The outcome of this ongoing research will expedite the certainty with which legal audiences can extrapolate our findings to legal settings.

I plan to expand upon this project beyond my time at Vanderbilt as well. Either in my own lab or through collaborations, I plan to continue to explore the results of Chapter 3 and bridge the gap between Chapter 2 and the on the ground reality the legal system is concerned with. This includes possibly recording EEG during contemporaneous or delayed audio narration tasks. In particular I would be interested in moving beyond ERP based experiments and looking more at time-frequency analysis. The results from Chapter 3 highlight some of the limits of ERP research where the lack of a true working memory load index for nonlateralized complex stimuli limited our ability to interpret our results. Theta band activity, for example, could be an intriguing alternative to ERPs and may be better suited to assessing cognitive load during complex lie scenarios such as our pie chart or audio narration task (Kahana, 2006).

My research agenda after Vanderbilt also expands beyond the PSI. My overall goal in research is to use my dual expertise to build a bridge from sound basic science which contributes to the scientific community to ecologically valid and legally relevant results that minimizes the need for extrapolation for the legal community. This can take the form of projects in my future lab where, like my dissertation project, we build novel paradigms that both advance our understanding of cognition and directly assess a legally relevant psychological assumption. It can also involve collaborations where I either work with other scientists to better tailor their research to directly assess legally relevant questions or work with other legal scholars to translate the relevance of neuroscience results to the legal community. In any of these settings my dual expertise allows me to help increase the scientific and legal impact.

The Federal Rules of Evidence are built on many psychological assumptions and I am excited to use the expertise I developed during my time at Vanderbilt to test those assumptions. One obvious target is the excited utterance which assumes that individuals are less capable of lying while under the stress of a startling event. This exception to the general hearsay ban is invoked frequently and the paradigms already developed over the course of my dissertation work provide tools directly applicable to testing its underlying assumption. Other targets beyond the hearsay exceptions include jury instructions allowing evidence to be useable for one use and not another or to disregard entirely improperly admitted evidence.

The work outlined in this dissertation not only helps advance our understanding of the cognitive processes of lie generation and assess the validity of the neurological and psychological assumptions behind the PSI, but also provides a path forward for the improved design of procedural rules. Neuroscience can facilitate a move towards empirically based rules that promote the goals of the legal system more effectively and efficiently than those premised on untested and often unspoken psychological assumptions.

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