THE 3DICE DECEPTION DETECTION DEVICE: QUANTIFYING DECEPTION AND ITS RELATIONSHIP TO THEORY OF MIND IN ADULTS

By

Joseph McGuinness
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Deceptive behavior has implications in many fields, and research by cognitive neuroscientists to uncover the functional brain networks utilized during lying and mechanisms of action is of great interest. Due to its clandestine nature, deception has proven especially difficult to measure and explain. Experimental design plays a crucial role when collecting data on the quantifiable manifestations of deception. Cognitive neuroscience models posit roles for theory of mind, cognitive monitoring, and response inhibition in both the production and detection of deceptive behaviors, especially in social situations. Yet, when Bond and Depaulo (2006) conducted a meta analysis of studies on lying, they found that less than 9% of studies incorporated social interaction between the “senders” and “receivers” of deception. Previous measures either utilize sanctioned lying, lack the social element, or lack precision and ecological validity. This thesis piloted a new measure of deception designed to improve upon previous measures by collecting the *frequency* (total lies told) and *fluency* (the difference in response times on truth trials vs. lying trials, otherwise known as response latency) with which participants lie on a trial by trial basis, in a social setting, and on their own volition. Thirty eight undergraduate students (17 female) between the ages of 18 and 34 from a large mid-Atlantic university were analyzed for *frequency* and *fluency* of lying on a new task designed to measure deception, as well as Theory of Mind ability via the Reading the Mind in the Eyes task. As hypothesized, people who lied more often also lied with less response latency, giving evidence for an overall lying ability or “deception quotient.” No correlations with Theory of Mind and lying were found. The 3Dice task offers myriad opportunities for future research into deception, operant reward, cognitive neuroscience, and economic theory.

The 3Dice Deception Detection Device:
Quantifying Deception and Its Relationship to Theory of Mind in Adults

Deceptive behavior has implications in intelligence operations, security clearance background checks, legal trials, and even psychotherapy (Bond & DePaulo, 2006; Furedy, Davis, & Gurevich, 1988; Sartori, Agosta, Zogmaister, Ferrara, & Castiello, 2008; Seymour, Seifert, Shafto, & Mosmann, 2000). Much research has been done in recent years by cognitive neuroscientists to uncover the functional brain networks involved during lying and to explain their mechanisms of action (Gallagher & Frith, 2003; Gohbini, Koralek, Bryan, Montgomery, & Haxby, 2007; Sabbagh, Bowman, Evraire, & Ito, 2009; Saxe & Kanwisher, 2003; Young, 2010). However, due to its secretive and clandestine nature, deception has proven especially difficult to measure and explain (Jenkins, Zhu, & Hsu, 2016). Knowing whether a person is lying at any point in a task is difficult to determine in an experimental setting unless the participant is explicitly directed by researchers to lie, otherwise referred to as ‘sanctioned’ lying (Bond & DePaulo, 2006; Spence et al., 2004). Without this sanctioned component of lying, participants can be asked to self report if they lied, or researchers can compare actual event outcomes (i.e. coin flips) to self-reported outcomes to determine if lying frequency changes in various experimental conditions (Karton & Bachman, 2011; Marechal et al., 2017). However, these methods rely on self report, pose problems with ecological validity, and/or do not allow researchers to study unsanctioned lying on a trial-by-trial basis (Jenkins et al., 2016).

The 3Dice Deception Detection Device (3Dice) is new measure I developed that can be used to examine unsanctioned lying in a social setting while recording reaction time data on each trial along with the truthfulness of each response. It is a computer based signaling game, run through the PsychoPy platform (Peirce, 2007), that utilizes monetary rewards to motivate participants to lie to an observer who is trying to catch them in the act of lying. With 150 trials, monetary motivation, a social setting, and instructions to lie on one's own accord for one's own interest, 3Dice has a number of advantages over current methods. This thesis piloted the 3Dice task in an experimental setting, and related frequency of lying and response latency on the task with Theory of Mind ability as measured by the Reading the Mind in the Eyes task (Baron-Cohen et al., 2001).

Quantifying Deception

Lying is a complex task. To successfully avoid detection, the person who is lying must calculate the odds of being caught, remember what they've already said, inhibit their natural propensity to tell the truth as well as any kinesthetic "tells" they might have, and choose a response they feel will be believable before making that response (Bond & DePaulo, 2006). Cognitive neuroscience models posit roles for theory of mind, cognitive monitoring, and response inhibition in both the production and detection of lying and other deceptive behaviors, especially in social situations (Spence et al., 2004). Yet, less than 9% of studies on deception incorporate even moderate degrees of social interaction between those lying ("senders") and those detecting deception ("receivers") (Bond & DePaulo, 2006).

Experimental design plays a crucial role when collecting data on the quantifiable manifestations of deception. DePaulo and Kirkendol (1989) found impaired control of non-verbal cues of deception (such as facial micro expressions or increased response latency) increase the difficulty of the sender's task, making detection easier. Caso et al. (2005) found that higher motivation, such as monetary reward, made the task of deception more difficult. They also found that participants reported greater guilt, anxiety, and cognitive load when lying than when telling the truth. These studies highlight the importance of social context when measuring deception. Studies that sanction lying or rely on self report can affect motivation and inhibition in ways that make lying behavior less realistic and yield results that lack ecological validity.

A few studies have attempted to inhibit lying through the use of brain stimulation techniques. In 2011, Karton and Bachmann presented a red or blue square and participants were told to identify the color truthfully or to lie about the color and say the other color. They found that spontaneous truthfulness increased with transcranial magnetic stimulation to the right dorsolateral prefrontal cortex (rDLPFC). However, with lies of such little consequence, this experimental design lacks ecological validity. In 2017, Marechal et al. used a probabilistic approach to evaluate lying. They had students flip a coin ten times with no observer and report the results to the experimenter in order to get paid based on the number of coins that landed heads-up. They found that anodal transcranial direct current stimulation to the rDLPFC was correlated with fewer occurrences of high numbers of heads flipped (7 or more) being reported. Both of these experiments found greater honesty with brain stimulation to the rDLPFC. However, the

Karton and Bachmann methodology lacks the motivation and inhibition that accompany real-world scenarios, and the Marechal study is based on probabilistic numbers and offers no way to examine what observable differences are occurring during the lying process. These studies have made claims about the use of brain stimulation to exert social influence on subjects, but without a more realistic approach to measuring lying in a social setting, these investigator's results lack a generalizability that would allow for real-world application.

Response Latency and Lying Frequency

A variety of methods have been employed in previous studies to better understand the cognitive processes involved with lying (Caso et al., 2005; Bond & DePaulo, 2006; DePaulo & Kirkendol, 1989; Spence et al., 2004). One of the key metrics being explored is the difference in response times (RTs) on truth trials vs. lying trials, otherwise known as response latency. Suchotzki et al. (2017) conducted a meta-analysis of 114 studies (total $N = 3307$) and found that "responding with a lie takes longer than responding with the truth." They estimated the size of the lie-truth difference in RT paradigms, and argued that large lie-truth differences support a cognitive theory of lying. This finding also seems to confirm the idea that lying typically involves more mental processing, which implies longer response times.

Reynolds and Short (2011) conducted conversation analysis during the television show, COPS, and timed the responses of alleged criminals responding to officers on the show. They found that increases in response latency occurred regardless of the presence or absence of lies in environments of denials and blame shifting which occur frequently between officers and suspects on the show. Their research found that transition space was part of an array of resources used to construct an interaction, and argued that a possible confound in research of response latency is the context in which lies are told. They demonstrated confounding variables that can impede the investigation of response latency when exploring 'vocal cues to deception' such as interactional context, complexity of the lie, and complainability (or the orientation as to whether something is worthy of a complaint as defined by the authors).

Walczyk et al. (2003) measured response latencies of sanctioned lies and found that response latency was significantly longer for participants when they lied. They also found correlational evidence for sender detectability (how easily someone can be identified as lying by an observer) and the difference in response latency for lies and truths. Sporer and Schwandt (2006) and Reynolds and Short (2010) also found longer response latencies before giving deceptive answers and under higher levels of motivation (meta-analytically and experimentally, respectively).

In addition to response latency, historical lying frequency is another commonly studied metric of lying (Bond & DePaulo, 2006; Suchotzki et al., 2017). People who lie more often have been shown to have shorter response latency than those who lie less often, possibly having ties to an "overall deception ability" (Reynolds & Short, 2010; Sporer & Schwandt, 2006). In 2010, Serota et al. conducted prevalence studies in which they showed that approximately half of all lies are told by 5% of people. Reasoning would suggest, based on these studies, that people who lie more often will also have faster response latencies when lying as compared to telling the truth.

Regardless of the study, it is clear the intent to deceive someone requires more cognitive processing than telling the truth. Some deception modulated network seems to be present which utilizes working memory, response inhibition, moral decision making, theory of mind, attention and other mental faculties to create and tell believable lies at the expense of greater cognitive load. This finding fits with the idea that lying typically requires greater mental capacity than telling the truth and suggests that one can use RTs to detect lies. Indeed, some RT paradigms allow for differentiating between lies and truths at well above chance levels (Verschuere & Kleinberg, 2016). Response Latency has been collected using several paradigms. Some of the most notable of these are the Concealed Information Test (CIT; Seymour, Seifert, Shafto, & Mosmann, 2000), the autobiographical Implicit Association Test (aIAT; Sartori, Agosta, Zogmaister, Ferrara, & Castiello, 2008), and the differentiation-of-deception paradigm (DoD; Furedy, Davis, & Gurevich, 1988).

Previous Measures of Deception

Concealed Information Test (CIT). In the CIT, participants are instructed to commit a mock crime on a computer involving the sending of incriminating information. After they had completed the mock crime scenario (and a distractor task), they participate in a “phrase classification task” in which probe items form the scenario were presented alongside control items taken from a different crime scenario which they had not seen or been a part of. Participants are presented with probes and instructed to press a button for ‘yes’ for a target stimuli and ‘no’ for all other stimuli. Participants are informed that a NO response to the salient stimulus is a lie and/or they are asked to hide recognition of the salient information to make the NO response to the salient stimulus a lie. The NO responses to the irrelevant stimuli are then averaged to provide a truth RT, and NO responses to relevant stimuli are averaged to provide a lie RT (Seymour, Seifert, Shafto, & Mosmann, 2000). Reaction times are longer when lying about salient items (ie., items related to the mock crime that they were involved in earlier in the experiment) giving support to the idea that RTs (response latency) can be useful in helping to identify deception.

Autobiographical Implicit Association Test (aIAT). The aIAT measures the difference in response times between two mutually exclusive autobiographical statements (e.g., "My name is Edward" vs. "My name is Steven") and the labels TRUE and FALSE. The core idea of the aIAT is that the response times associated with the statements paired with TRUE versus FALSE provides information on their truthfulness. When the participant pairs "My name is Edward" with TRUE faster than "My name is Steven" with FALSE, one can infer the participant's name is Edward (Sartori, Agosta, Zogmaister, Ferrara, & Castiello, 2008).

Differentiation of Deception (DoD). The (Differentiation of Deception paradigm) DoD (and the Sheffield Lie Test) present(s) the participant with a series of Yes/No questions (e.g., "Is your name Edward?") along with instructions for the participant to answer some questions truthfully and others deceptively (e.g., "Lie about your name, but don't lie about your birthday") based on an experimental manipulation (ie., when the question is in white, tell the truth, and when the question is in black, lie) (Furedy, Davis, & Gurevich, 1988).

Improving on Previous Measures of Deception

The CIT was successful in showing that reaction times (response latency) can be a useful metric in identifying deception, but its design, as a hybrid go/no go task may induce response inhibition that could interfere with people lying (Selle et al., 2015). Also, participants are sanctioned to lie in the CIT which decreases the ecological validity of the data and the salience of the irrelevant items may be confounding because it uses names that may or may not have salience to a subject. The aIAT measure could work well in a polygraph setting in that it provides data on a metric associated with lying (reaction times). However, if the subject knew about this metric, s/he could eliminate the difference by pausing before all answers regardless of their truthfulness. It would not work well in an experimental setting designed to measure differences in response latency because the true condition occurs far less often than the false condition, reducing the power of statistical analyses. This measure could also be influenced by the salience of names or terms for each participant, much like the CIT. The DoD task is another sanctioned lying task, in that the experimenter is directing the participant to lie under certain conditions rather than under their own free will. The mental processes involved in sanctioned lying are likely different from those involved in unsanctioned lying, especially in a social setting where the consequences of being caught would weigh much more heavily on a person's decision to lie or not (Freeley & deTurck, 1998).

The studies above have been largely designed to isolate the individual components of lying, by proxy eliminating ecological validity through saliency, sanctioning, or removal of stress associated with lying in a social setting. None of these previous measures are capable of measuring minute changes in reaction time differences for unsanctioned lying due to experimental manipulations on a trial by trial basis. 3Dice is a new measure of deception that I developed that calculates the total number of lies told along with the response latency and veracity of each trial in a social setting. This measure offers advantages over other measures because of its precision in measuring response latency and its ability to determine the truthfulness of individual responses in a social context. 3Dice always keeps the task the same and measures the truthfulness of each response directly and independently. It offers more opportunities for people to lie in a more realistic setting that does not instruct participants to lie and presents trials with no personal salience to the participants. This design creates more ecological validity and allows for analyzing response latency in a social setting which is necessary in order to understand how specific functional networks are utilized in deception because deception is typically a social behavior involving two or more people. In order to lie, the liar must be aware that different people could have different beliefs (different perspectives on reality), that people can be influenced to form false beliefs about reality, and that their actions could be altered by those false beliefs (Lee, 2013). So, one of the abilities that may be involved in lying effectively without being caught is the ability to form a mental representation of another person's thoughts or beliefs, also known as Theory of Mind.

Theory of Mind

Theory of Mind (ToM) is a term coined by David Premack and Guy Woodruff, in 1978, to represent the ability of humans to read below another person's surface behavior and attribute intent to their actions (Meltzoff, 1999; Premack & Woodruff, 1978). It is one of four abilities that are named by Kolb and Wishaw (2015) as being unique processes of humans (the others being grammatical language, phonological awareness (the ability to recognize and work with sounds in spoken language), and special forms of intelligence i.e. intuition). Saxe and Wexler (2005) gave a more refined definition of theory of mind, calling it the process by which humans (1) ascribe mental states to others and (2) incorporate those states into a representative model that can explain and predict their behavior and experience.

A good deal of attention to the development of theory of mind in children has emerged recently in the literature. Young, Cushman, Hauser, and Saxe (2007) investigated the manner in which children formed moral judgements when presented with conflicting information about an actor's intention and the outcome of their actions. Looking from a developmental perspective, they saw integrating information about mental states and outcomes to be particularly challenging for young children because they have less sensitivity to the intentions of a person's actions. Their study showed that as children get older, they develop theory of mind and, along with it, the ability to integrate intentionality with consequences to form a more nuanced or complex basis for moral judgement. They investigated this interaction with a 2X2 design consisting of vignettes with a negative outcome or neutral outcome (someone's death vs. no death) vs. a protagonists' belief that they would cause a negative outcome or not. The data showed that young children attributed more guilt when the protagonist caused "unknowing harm" than when they attempted harm but failed. This conclusion would indeed give evidence for the hypothesis that young children do not attribute guilt based on intentionality as much as older children do.

Another study on ToM in children was completed by Ding, Wellman, Wang, Fu, and Lee (2015). They began their investigation looking into the effects of ToM in children's social competence and popularity in school with their peers to find that it was highly predictive of both. They went about their study by training three year old children in theory of mind tasks and correlating the training they received to their ability to win at a lying game with enduring "positive" results. Ding et al. suggested that ToM aids in children's ability to understand when it is appropriate to lie and what to lie about. It also aids them in being able to concoct believable lies by allowing them to representationally create a false belief in the recipient's mind through the telling of their lie. Their study involved a hide and seek deception task given to three year old Chinese children who were selected based on their inability to lie before the experiment. They gave training with direct feedback on two false belief tasks and one appearance-reality task to children in the experimental condition. The children in the experimental condition were also read stories with "mental-state vocabulary" and asked questions about the content of the stories afterward. The children in the experimental condition were found to improve significantly in their performance on the hide-and-seek deception task compared to children in the control group and to their own pretest scores. The findings also had an enduring quality to them with the children maintaining a higher score on the hide-and-seek task over a month after the task and into the future. This study supports the idea that

Theory of Mind training can improve a child's ability to deceive, and therefore also supports the idea that Theory of Mind is an important component in lying behavior.

Recently, some experiments have investigated Theory of Mind through the use of functional brain imaging. A study by Sabbagh, Bowman, Evraire, and Ito (2009) looked at "representational" theory of mind (RTM) in young children that appears as early as 10 months, but usually emerges between three and five years of age and tends to hit ceiling performance at around five years of age. The term representational theory of mind is referring to "person specific representations of the world." One exception to this developmental timetable lies in children with autism who showed impaired development of RTM. They conducted a neural imaging study showing that differences in density estimations in the right temporo-parietal junction of preschoolers was highly predictive of their performance on tests of representational Theory of Mind. These findings concurred with similar studies associating ToM to the same brain areas in adults. From these data, they deduced a hypothesis for a domain specific role of the rTPJ in ToM reasoning. They found that the same regions associated with visual attention shifting (in a nonsocial context) did show some overlap with the regions responsible for RTM. However, their regression analyses found that the additional regions' contributions had been mediated through relations to rTPJ or dmPFC.

Gallagher and Frith (2003) were among the first to explore the functional imaging of Theory of Mind. They presented subjects with a series of stories described as either "familiar" (reflecting a moderate Western background) or "Foreign" (with respect to geography, religion, wealth or politics). The protagonists of the stories had "Normal" or

“Norm-violating” mental states (from their own perspective) with each “Norm-violating” mental state being compatible with the “Foreign” background. Finally, the protagonists were either left satisfied or unsatisfied with the outcome. Using fMRI analyses of the BOLD response (blood oxygenation level dependent), they measured neural activity in a number of regions and compared the response of each region of interest when mental state information was either delayed (by 6 seconds) or available immediately. Their study showed a hemodynamic response in the right temporo-parietal junction that reflected both characteristics of a Theory of Mind as they defined it. Their findings point to the rTPJ as being responsible for attributing mental states, but not other socially relevant facts to someone. This study gave strength to the idea that the rTPJ had more involvement in ToM processes than other brain regions. Multiple fMRI studies have since demonstrated the blood oxygen level dependent response (Gohbini, Koralek, Bryan, Montgomery & Haxby, 2007; Saxe & Kanwisher, 2003; Young, 2010). They’ve shown greater activation in the rTPJ as well as the LTPJ, mPFC (medial prefrontal cortex), and precuneus on Theory of Mind tasks with relative consistency.

As has been shown in the literature, people who have strong ToM abilities The current thesis study utilized the 3Dice task to investigate some of the most basic tenets of deception while exploring the role of Theory of Mind and how it correlates with observable metrics of lying. In order to set the stage for future investigations into lying behavior, this study investigated the role of Theory of Mind processes in the art of deception and piloted the 3Dice task as a measure of frequency (number of lies told) and fluency (response latency) in adults. After completing the Reading the Mind in the Eyes task (Baron-Cohen et al., 2001), subjects came in to the lab for the 3Dice task. Based on the idea of an overall deceptive ability, it was hypothesized that people who lie more often would lie with shorter response latency. Based on the involvement of Theory of Mind in deception, it was hypothesized that people with higher scores on the Reading the Mind in the Eyes task would be better liars and therefore have a greater number of lies told (lying frequency) and a shorter response latency for their lyving (lying fluency).

Method

Participants

Thirty eight undergraduate students (17 female) between the ages of 18 and 34 years (Mean age = 22.22 years, *SD* = 3.83) from a large mid Atlantic university participated in this experiment in exchange for monetary compensation based on performance. Students were recruited with a paid research opportunity, rather than course credit, because their compensation and performance on the task were monetarily based in order to increase motivation. The group had normal or corrected to normal vision, verified by the Snellen eye chart before participating in the experimental sessions. Two subjects (from an original sample size of 40) were removed as outliers because they lied on every trial (Number of lies told = 150) and it was deemed that they did not understand or did not follow the instructions.

Materials

Stimuli were presented on a desktop computer. A GoPro Hero3 webcam was placed above the computer and directed at the participant to instill the presence of an observer on them while completing the 3Dice task. The 3Dice task was programmed on PsychoPy coding language (Pierce, JW, 2007) and presented on a laptop. Motorola Walkie Talkies were utilized to reinforce the observer's presence through scripted interruptions at 270 seconds and 510 seconds (see Appendix C).

Measures

3Dice Deception Detection Device. The 3Dice Deception Detection Device (3Dice), developed for this study, was utilized to collect deception-related data (number of lies told, response latency) on the participants. 3Dice is a signaling game, run through PsychoPy (a coding language for Psychology based on the Python coding language), in which participants roll three dice on a computer screen while being observed over webcam by an observer who was trying to catch them in the act of lying about whether they guessed (reported a high roll or low roll) correctly. They were instructed (full instructions in Appendix D) to guess whether the roll would be high (11-18) or low (3-10) by pressing either the up or down arrow on a keyboard. Once the roll appeared, participants were presented with a screen that displayed the number rolled and immediate visual feedback on whether the roll was high or low. The participants were given 5 seconds to respond by pressing the right arrow to "tell the truth" (about their guess being correct or incorrect) or the left arrow to lie about their roll (for a chance to win more money). If they guessed correctly about their roll and told the truth, they won 25 cents. If they guessed correctly about their roll and lied, they won 50 cents if the observer guessed that they told the truth and lost 50 cents if the observer guessed that they lied. If they guessed incorrectly about their roll and told the truth, they won nothing. If they guessed incorrectly about their roll and lied, they won 50 cents if the observer guessed that they told the truth and lost 50 cents if the observer guessed that they lied.

A series of screenshots from a sample trial of 3Dice is included in Appendix E. A decision tree with all possible behaviors and outcomes for the participants labeled with the monetary reward associated with each outcome is included in Appendix F. Based on the setup of the game and the possible monetary outcomes, the strategy that would create the highest score would be for the participant to tell the truth on trials that they guessed correctly and to lie on trials that they guessed incorrectly. Since the computer randomly guesses that the participant lied 40% of the time, they have a 60% chance of winning 50 cents and a 40% chance of losing 50 cents when lying about an incorrect guess. For a correct guess, the participant would be wagering the 25 cents that were won, effectively creating a loss of 75 cents when they are caught and a gain of only 25 cents if they are not caught.

Each participant was given a practice round of 10 rolls to familiarize themselves with the rules of the game before the experimental trials began. If they had further questions or were still unsure that they understood the rules (which happened about 1/3 of the time), they could ask questions of the experimenter and were given more practice rolls until they were comfortable in their understanding of how the game worked.

The participants were told that they were being observed over webcam while participating in the task and that an observer was trying to catch them in the act of lying. A GoPro was also used to reinforce the idea of an observer’s presence. It was set up above their experimental computer screen and the participants saw video of themselves being streamed to the observer's computer during setup. The observer then brought their computer with the video stream of the participant to another room, but the observer did not use it in any way. In actuality, 3Dice was programmed to randomly guess that the participant lied 40% of the time. Artificial responses from the observer were jittered to occur 2-4 seconds (in 0.1 sec increments randomly generated by PsychoPy) after the participant responded to their roll, rather than occurring in exact time increments in order to make the algorithm appear less mechanical and instill the presence of a human observer. The “observer” was necessary in order to create a social setting that would elicit natural lying behavior from participants who believed that they were being watched. The observer also called in, via walkie talkie, at predetermined interruption times, reading go pro adjustments from a script to reinforce their presence (see Appendix C for script).

Reading the Mind in the Eyes. Reading the Mind in the Eyes is a computer-based measure of Theory of Mind. Participants are asked to identify an emotion represented in 36 pictures of people’s eyes conveying various emotional expressions (Baron-Cohen et al., 2011). The participants are shown a picture of someone’s eyes (see Appendix G). They select the emotion that they think the eyes are associated with from four possible choices. A higher score on this is associated with higher level Theory of Mind, or ability to correctly attribute mental states to another person. Participants were asked to complete Reading the Mind in the Eyes (RTMITE) before participating in the experimental sessions.

Analysis

Subjects were analyzed for *frequency* and *fluency* of lying. The 3Dice task collected data on total number of lies (#L) as well as the response latency for each trial. An average time to tell a lie (xLt) and an average time to tell a truth (xTt) were computed. A mean difference (xDt) was calculated by subtracting xTt from xLt (xLt – xTt = xDt). xDt will now be referred to as *response latency* or *fluency*. Based on the literature (Reynolds & Short, 2010; Sporer & Schwandt, 2006), response latency and lying frequency should correlate, with those who lie more often exhibiting greater fluency (shorter response latency). Participant's scores on the Reading the Mind in the Eyes task was also used in data analysis to represent a person's Theory of Mind. It was hypothesized that higher frequency of lying would correlate with shorter response latency (for lies relative to truths), higher Theory of Mind scores were expected to correlate to greater number of lies told and lower response latency.

Results

A Pearson bivariate correlation was run for number of lies told (frequency) (mean = 48.82, SD = 22.31) and response latency (fluency) (mean = .1616, SD = .2468). There was a broad range in number of lies told with values ranging from 2 to 87. As hypothesized, people who lied more often also lied with less response latency (r = -.355, p = .029) (Figure 1). The negative relationship was expected, due to the fact that a faster response latency is indicative of a lower score. For fluency, a mean of .1616 means that participants took an average of .1616 seconds longer to tell a lie than to tell the truth over the course of 150 trials (range of -.535 to .606 sec). The average fluency was positive as expected. It was theorized, as outlined previously, that in telling a lie, there is more time used in a number of mental processes believed to be incorporated for deception. Each of these mental processes takes time which results in a greater amount of time being taken for a lie to be told than a truth.

Participant's scores on the Reading the Mind in the Eyes task (RTMITE) were analyzed as a proxy for Theory of Mind ability. Bivariate correlations were run for Frequency x RTMITE ($r = -.24$, $p = .141$) and Fluency x RTMITE ($r = .12$, $p = .478$). Figure 2 (a) and (b) shows these data. The correlations for both of these relationships were nonsignificant.

Discussion

Many researchers in the field of cognitive neuroscience are working to understand the functional brain networks utilized in deception (Gallagher & Frith, 2003; Gohbini, Koralek, Bryan, Montgomery, & Haxby, 2007; Sabbagh, Bowman, Evraire, & Ito, 2009; Saxe & Kanwisher, 2003; Young, 2010). A person who is lying must calculate the odds of being caught, remember previous responses, and choose a believable response while inhibiting their natural propensity to tell the truth as well as any kinesthetic "tells" they might have (Bond & DePaulo, 2006). Previous measures of deception, including the CIT (Concealed Information Test), aIAT (Autobiographical Implicit Association Test), and DoD (Differentiation of Deception test), have all been informative in evaluating the behaviors associated with lying, and have highlighted the importance of response latency as a common metric that can be utilized to differentiate a true response from a lie (Seymour, Seifert, Shafto, & Mosmann, 2000; Sartori, Agosta, Zogmaister, Ferrara, &

Castiello, 2008; Furedy, Davis, & Gurevich, 1988). However, due to confounding factors such as response saliency and the sanctioning of lying in their tasks, they fail to provide a way to observe differences in naturalistic lying behavior in a social context.

Experiments utilizing brain stimulation to increase honesty in humans have been conducted recently and have successfully shown that their samples were more likely to behave in an honest manner after undergoing tDCS (transcranial direct current stimulation) or TMS (transcranial magnetic stimulation) to the rDLPFC (right dorso lateral prefrontal cortex) (Karton & Bachman, 2011; Marechal, Cohn, Ugazio & Ruff 2017). These experiments are ground breaking in that they have shown that brain stimulation can be used to exert social influence on subjects. It is important that these studiy results be replicated in order to give greater validity to their findings. In replicating these findings, it would be prescient to improve upon the experimental design and use a measure of deception that is not based on probabilistic inference or sanctioned lying. It would also be helpful to investigate and quantify new metrics of deception that can further our understanding of the neurological happenings when a person lies.

Since reaction time is so prevalent in the literature as a metric for discriminating between truthfulness and deception (Seymour, Seifert, Shafto, & Mosmann, 2000; Sartori, Agosta, Zogmaister, Ferrara, & Castiello, 2008; Furedy, Davis, & Gurevich, 1988), it is useful to have a measure of deception that is capable of picking up on minute changes in reaction time along with the veracity of responses on a trial by trial basis. With this information, it would be possible to validate brain stimulation paradigms, associated to different regions of brain, as being effective in lengthening response time (response latency or *fluency*). If the average response latency is altered on a lying task during a brain stimulation paradigm, it would reasonable to think that that brain region is involved in some part of the act of deception. Since deception is social in nature, it would also be useful to include a social element into the experimental design in order to increase the ecological validity of the study.

This study piloted the 3Dice Deception Detection Device as a new measure of deception, capable of measuring the frequency and fluency of unsanctioned lying, on a trial by trial basis, in a social setting. Participants were asked to complete a measure of Theory of Mind (Reading the Mind in the Eyes) before coming in to the lab where they completed the 3Dice task which measured the total number of lies told (frequency) and the veracity of each response along with the reaction time. The average reaction time for trials in which they lied and those in which they told the truth was calculated and a difference between those two numbers was calculated to provide a new metric (fluency). As expected, frequency and fluency were correlated in an inverse relationship where people who lied more tended to lie more quickly. This relationship between frequency and fluency may be related to some kind of overall lying ability or "deception quotient." 3Dice, overall, has shown to be excellent at measuring what it was designed for, as it measures the total number of lies told during the experimental session (frequency) in a social setting and gives feedback on a trial-by-trial basis for the veracity of each response along with the difference in response latency between truthful trials and trials in which the participant lied (fluency).

Limitations

This experiment failed to show a relationship between scores on Reading the Mind in the Eyes and frequency or fluency. This could be due to a deception network that relies less on social cognition and more on executive functioning. This could also be due to the lack of discriminability in Theory of Mind ability in neurotypical adults. The Reading the Mind in the Eyes task has been widely used in a variety of studies to operationalize Theory of Mind in adults (Khorashad, 2015; Pinkham et al., 2014) and when developing the experiment was thought to be a reasonable method to use for this purpose. However, a recent IRT (Item Response Theory) analysis has shown that it fails to discriminate theory of mind ability in neurotypical adults and a more sensitive instrument would likely help to solve this problem (Black, 2018).

Theory of Mind is a difficult construct to measure accurately, especially in a neurotypical adult population. Some have argued that it is a two system construct consisting of separate implicit and effortful processes that would complicate this matter even further (Apperly & Butterfill, 2009). Apperly and Butterfill (2009) argue that the competing demands of efficient and flexible processing of attributed emotions and thoughts are solved by having two systems; one being an early developing system which is efficient but inflexible, the other developing later and depending on linguistic abilities, which is more flexible, but requires more explicit effort on the part of the individual. Others argue that theory of mind (or mind reading) relies on one system, which operates autonomously when it can, but develops to incorporate and work with domain general resources (such as working memory and spatial rotation) when necessary (Carruthers, 2016). The Reading the Mind in the Eyes test was developed to measure “mentalizing” or Theory of Mind in clinical populations (eg. schizophrenia, Asperger’s) for which it works well, but it has been used in a number of studies of non clinical samples in recent years to operationalize constructs including empathy, mind reading, and interpersonal sensitivity (Black, 2018). Studies have found that in neurotypical samples, it measures emotional recognition (Oakley, Brewer, Bird, & Catmur, 2016) or intelligence (particularly verbal IQ) better than Theory of Mind (Baker, Peterson, Pulos, & Kirkland, 2014; Peterson & Miller, 2012). Due to the lack of research on deception and theory of mind in neurotypical adults, the answer for how to better understand this idea is better left to future investigations.

As with many studies, this study could benefit from a larger and more diverse sampling of participants in order to increase power and representativeness of the results. Another limitation to this study is the believability of the quasi social design. The go pro video stream and scripted walkie talkie prompts were designed to instill the presence of an observer on the participants, but it might be a stronger design if there were an actual observer guessing whether the participants were telling the truth about their rolls or not. One thing that this experimental design was attempting to avoid was the confounding presence of an observer in the room with the participants. Variables such as attractiveness, similarity, rapport would be difficult to control for in a situation like that. By removing the observer from the immediate vicinity of the participant and always having the same observer setting up the video stream and calling in with the go pro adjustments, it was hoped that those variables were controlled and would not influence the data. It was also important to have an equal likelihood of guessing that a participant lied on a roll during each experimental session, and this would be difficult to control for if an actual human observer were making the guesses. So, a quasi social design was adopted to allow for data to be captured while participants believed that they were interacting with another human rather than a computer while controlling for those variables. It would have been a good idea to collect data on whether or not the participants believed that they were interacting with a human during the task as this could be important information based on the hypotheses being tested.

Future Directions

Two studies have utilized brain stimulation to investigate the possibility of increasing honesty through brain stimulation to the rDLPFC (Karton & Bachmann, 2011; Marechal, 2017). After piloting this 3Dice measure, the next step will be to replicate these findings while utilizing 3Dice as the measure of deception. These findings have important implications for the field of cognitive neuroscience as they give support to the idea of a mechanical form of social control. If it is true that brain stimulation paradigms can be used to influence the number of lies a person tells on a simple task, these findings would validate that the mind is a malleable organ, which under certain conditions operates in a predictable way that can be manipulated via electrical impulse. As Marechal et al. (2017) have shown, tDCS to the rDLPFC should increase honesty in subjects and lead to lower frequency of lying in subjects under the stimulation condition. As Karton and Bachmann (2011) have shown, TMS to the rDLPFC should also increase honesty in subjects. Furthermore, the rTPJ should become a target of future brain stimulation studies designed to increase honesty. As has been shown by Saxe and Wexler (2005) the rTPJ is involved in ToM processes, especially in attributing mental states to another person. Therefore, under social conditions, the rTPJ may prove to be more heavily incorporated in deceptive behavior.

There are advantages to 3Dice as a measure of deception that are outlined previously and these should be utilized in future studies. For one, 3Dice allows a trial-by-trial analysis of response latency and veracity. This is important for a number of reasons. For one, it will allow for more in depth analyses of lying behavior. New categories can be constructed for further analyses of decision making behavior in the deception process. One metric that 3Dice will allow researchers to look at in future studies is if lying behavior changes after a subject is caught in the act of lying. Since 3Dice is capable of determining the veracity of each individual trial, it is possible to create a new variable that looks specifically at trials that occur after a participant is caught lying (ie "After Caught"). This "After Caught" variable could be examined for differences that occur on a global scale (ie., do people tend to lie less often after being caught lying?), as well as on a between-subjects scale based on personality characteristics (ie., do people who score high on thrill seeking or other traits linked to psychopathy lie more often after being caught lying?).

Another advantage to the 3Dice paradigm, over previous measures of deception is the "crux position" created in the decision tree. As highlighted in Appendix F, this position is different from other positions on the tree in that the participant is actually risking 25 cents in order to have a chance to win more money. This crux position was created based on prospect theory (Glockner & Pachur, 2011) and the idea that someone will have to get a reward of approximately 2x what they have already won in order to risk their winnings for a chance to win more money. 3Dice and the decision tree created for it will allow for analyses of operant reward in testing prospect theory by varying the amount of the reward given for each scenario on the decision tree (ie., will a chance of winning 75 cents or more in the crux position create a scenario that entices people to lie more often?) By varying the amount of reward given in blocks of trials, it should be possible to parse together how much reward is optimal for producing the maximum amount of lying for the minimal amount of reward. Again, this could be analyzed on a global scale or by correlating certain personality characteristics such as psychopathy, social desirability, and altruism to lying behavior rewarded by varying amounts. 3Dice could also be utilized to inform economic theory, as Kajachaite and Gneezy (2017) have found while studying incentives and cheating, some levels of reward are so high that they actually reduce the amount of cheating on a task, possibly due to a perceived threat of detection.

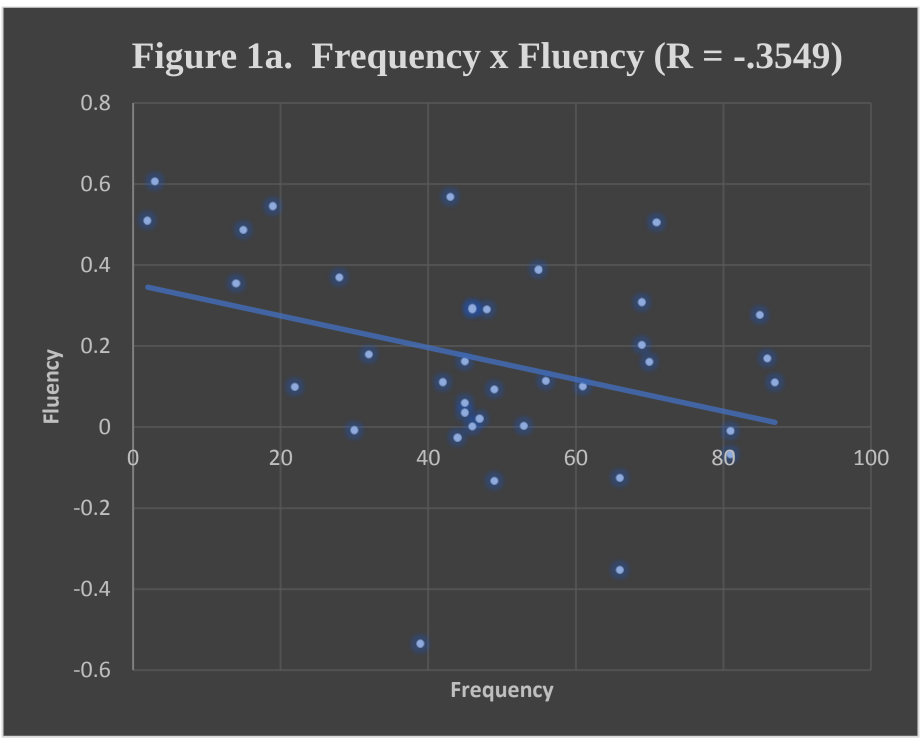
As is seen in the range of data for lying frequency in this experiment, some people seldomly choose to lie. These people may offer new insight into deception. It may be possible to run neuroimaging experiments in which these people and people who lie often (ie., more than half of the trials) are given sanctioned lying tasks and/or sanctioned tasks where they are instructed to tell the truth. In comparing the neural networks of these groups, functional networks may be parsed from the data that increases our understanding of different personality types or approaches to lying.

3Dice incorporates a quasi-social element in its design. By utilizing a GoPro video stream and walkie talkies to instill the presence of an observer, this experiment has theoretically induced a social element to a lying experiment. Very few studies on deception have incorporated any amount of a social element into their experimental designs. In so doing, 3Dice may allow for research into the different brain networks utilized in deception in a social situation vs. a computer with no mind. An example of such an experiment would be to have participants in a functional MRI scan complete the task in blocks, some of which incorporate a living observer and some of which are purely a computer algorithm. By comparing the functional imaging of the two conditions, it stands to reason that differences would emerge between lying to a person and lying to a computer. This would further our understanding of the functional networks involved in deception, especially in interpersonal deception.

The experimental design could also be augmented by including an *actual* observer who is trying to guess whether a person is lying on each trial, or by incorporating facial recognition software designed to do the same thing (possibly even validating the effectiveness of such software). If an actual human observer is incorporated into the experimental design, brain stimulation studies could be designed that seek to augment a person's ability to detect a lie, bringing the study full circle and augmenting the polygraph by enhancing the polygrapher's own abilities at detecting a lie while inhibiting the subject's ability to tell one.

Appendix A

Figure 1



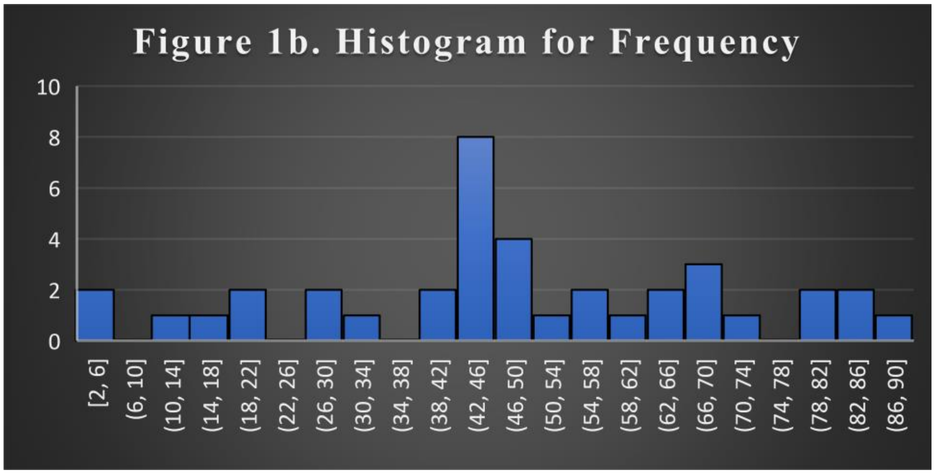


Figure 1b. Histogram for Frequency

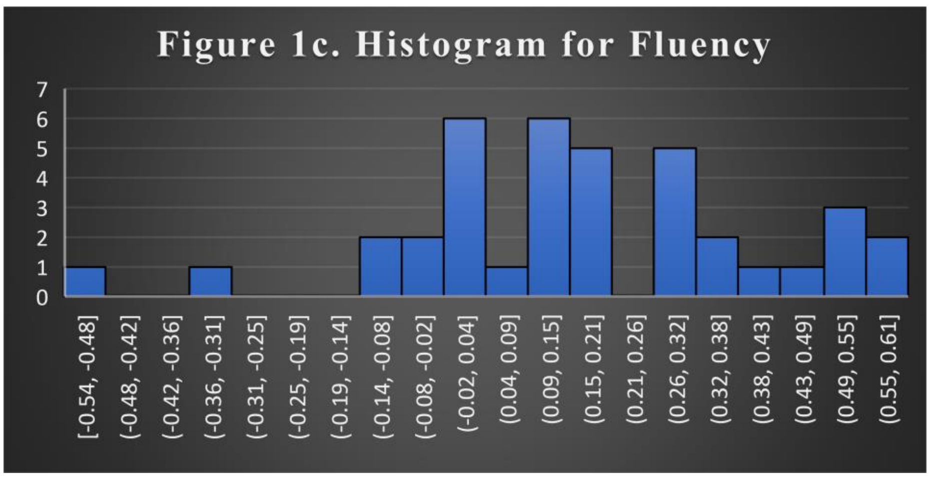
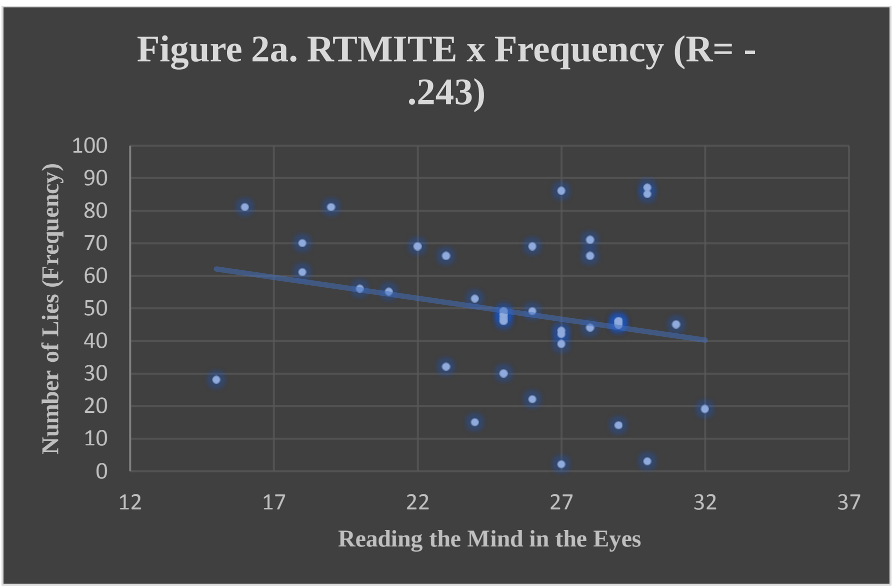


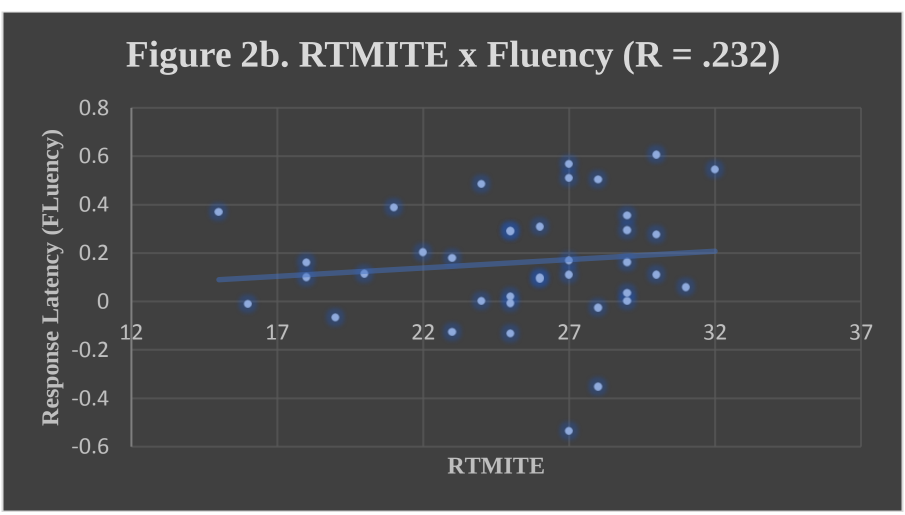
Figure 1c. Histogram for Fluency

Figure 1a is a scatterplot of Frequency (Number of lies told) x Fluency (difference in response latency for lies vs. truths). Figure 1b & c are histograms for Frequency and Fluency.

Appendix B

Figure 2





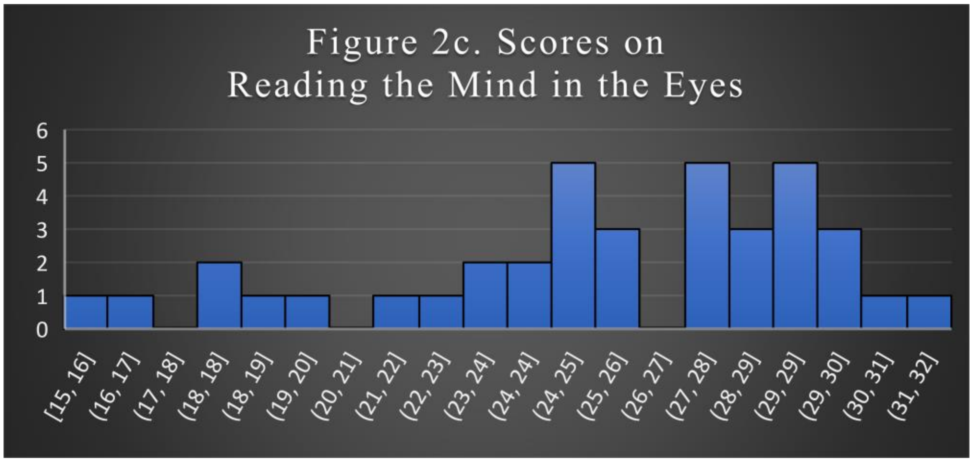


Figure 2a is a scatterplot of scores on the Reading the Mind in the Eyes task vs. Number of lies told (Frequency). Figure 2b is a scatterplot of scores on the Reading the Mind in the Eyes task vs. Response latency (Fluency). Figure 2c is a histogram for scores on the Reading the Mind in the Eyes task.

Appendix C

Observer's Script (read over walkie talkie):

Begin Experiment (0 seconds): observer called in to a confederate "View is clear, begin experiment".

Interruption 1 (270 seconds): observer pressed call button, confederate instructed participant to pause, observer said "I do not have a full view of the participant, please adjust the GoPro slightly to the left". After adjustments were made, the confederate called back to the observer, "Adjustments made, do you have a clear view of the subject". The observer replied, "view is clear, resume experiment".

Interruption 2 (510 seconds): observer pressed call button, confederate instructed participant to pause, observer said "Please ask the participant to sit up straighter in the chair". After adjustments were made, the confederate called back to the observer, "Adjustments made, do you have a clear view of the subject". The observer replied, "view is clear, resume experiment".

Appendix D

Instructions:

"Thank you for participating in this experiment. You will be playing a game called 3Dice.

The game rules and controls are as follows: You will have 150 rolls. You will roll 3 dice. A HIGH roll is equal to 11 or greater. A LOW roll is equal to 10 or less. You roll the dice by pressing up or down when ready. Press UP to guess HIGH or DOWN to guess LOW. Your roll will appear and you will have 5 seconds to decide to lie to the observer or not.

WHILE THE DICE ARE ON THE SCREEN.   Press LEFT to LIE or press RIGHT to TELL THE TRUTH.

If you guess correctly, you win 25 cents. If you guess incorrectly, you win nothing, but you will have the chance to lie about your roll and still win money. You can lie about your roll whether you won or not.

An observer will be watching you over webcam and attempting to correctly guess whether you lied about your roll. Your observer will then be given 5 seconds to catch you in the act of lying.

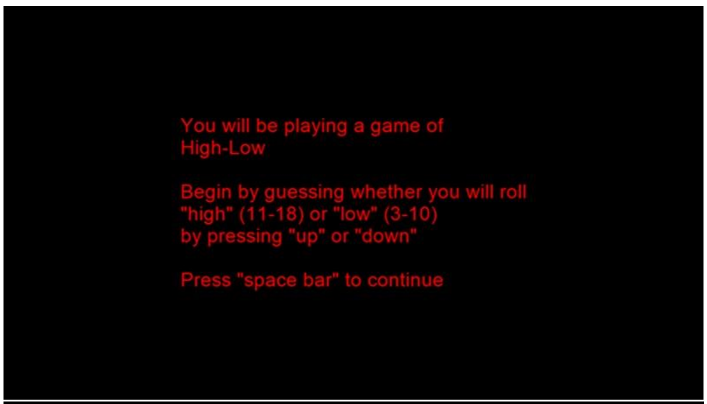
If you lie and are not caught by the observer you will win 50 cents. If the observer catches you, you will lose 50 cents. After the observer has responded you will see if you won or lost and the next trial will begin.

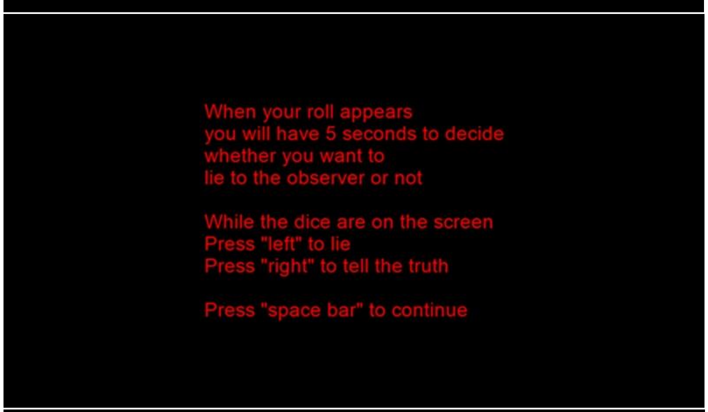
The object of the game is to make as much money as possible. Whatever your total is at the end of the 150 trials is what you will win for participating. Now you will play a 10 roll practice round to familiarize yourself with the game rules and controls. "

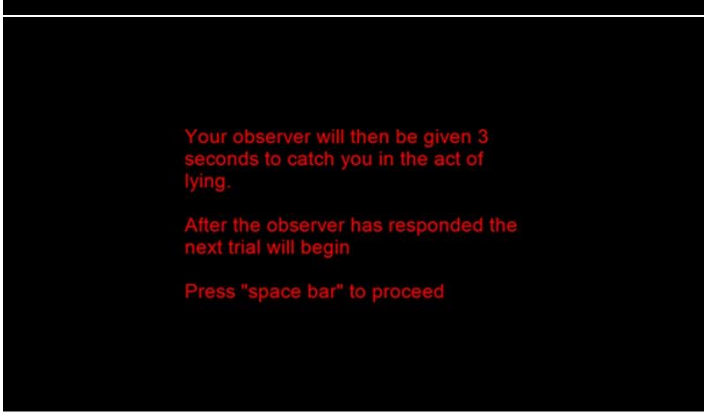
DO NOT READ: HAVE PARTICIPANT PLAY THE PRACTICE ROUND AND FEEL FREE TO ANSWER ANY QUESTIONS THEY HAVE WHILE PLAYING THE PRACTICE ROUND.

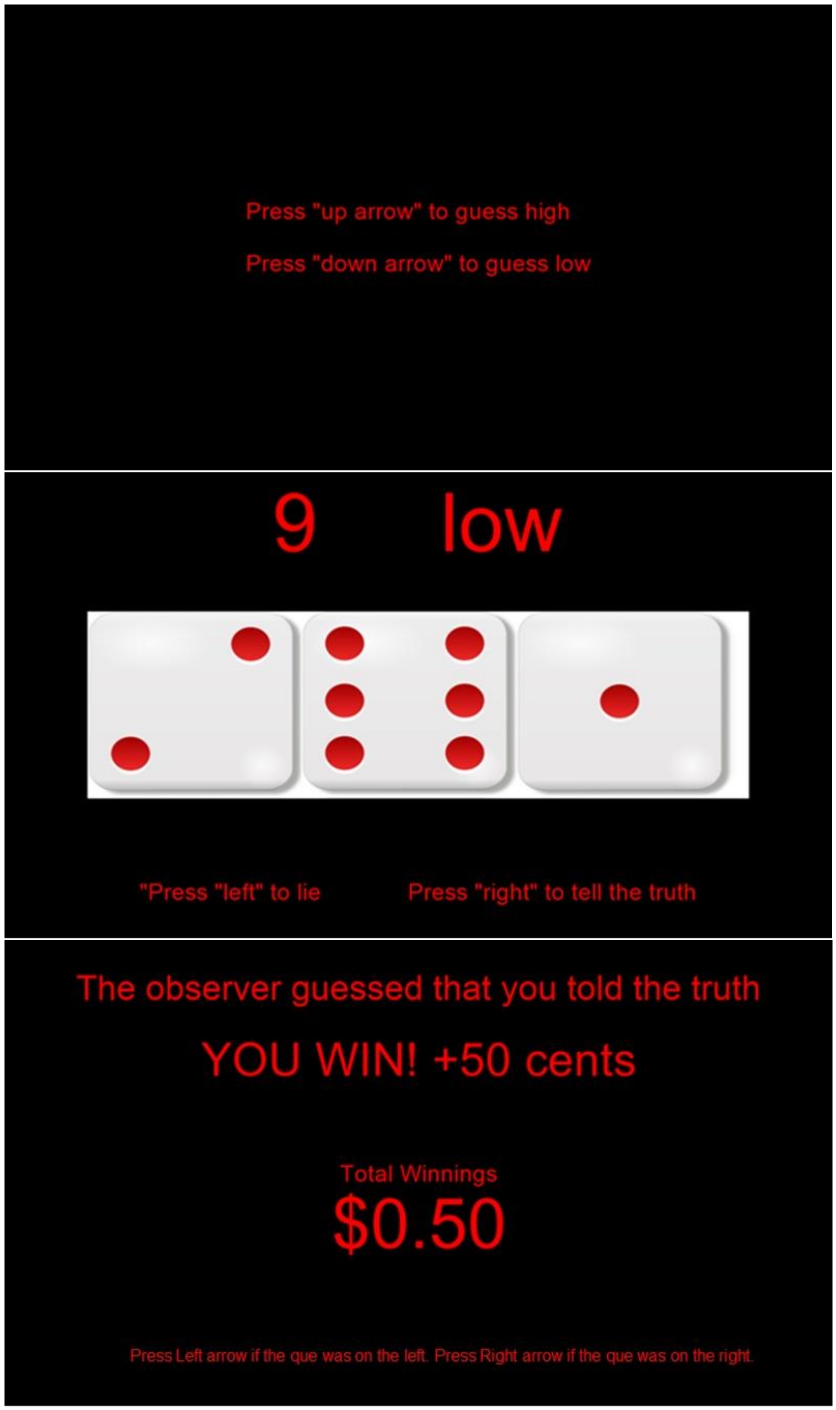
Appendix E

Screenshots from sample trial of 3Dice:



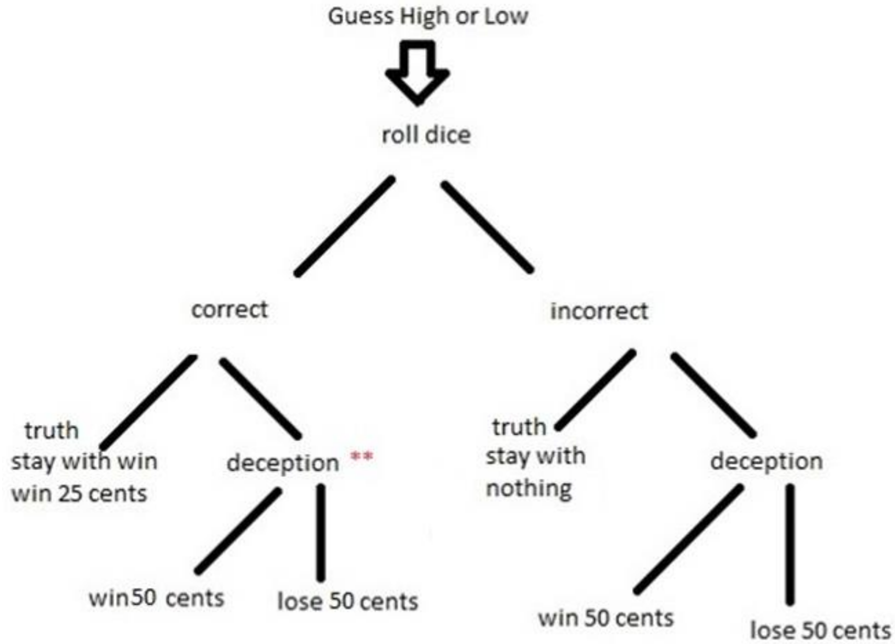





Press "up arrow" to guess high
Press "down arrow" to guess low
9
low
"Press "left" to lie
Press "right" to tell the truth
The observer guessed that you told the truth
YOU WIN! +50 cents
Total Winnings
$0.50
Press Left arrow if the que was on the left. Press Right arrow if the que was on the right.

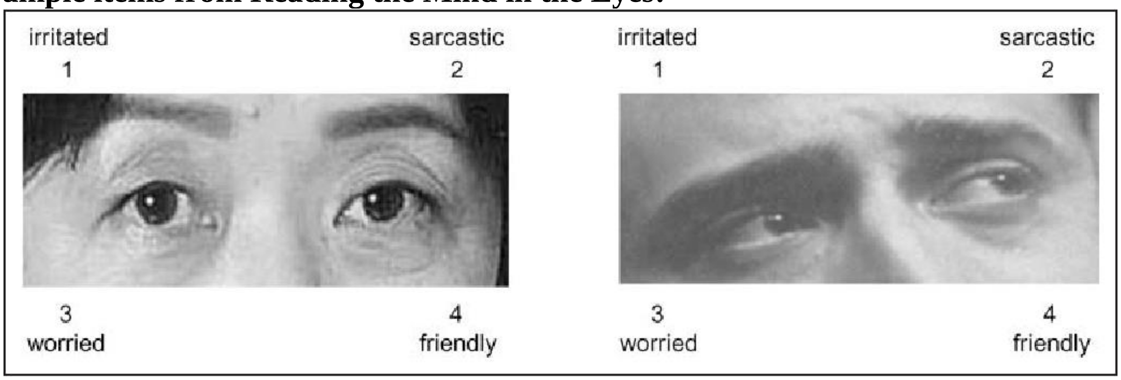
Appendix F

3Dice decision tree:



Appendix G

Sample items from Reading the Mind in the Eyes:



(Adams et al., 2010)

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Biography

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