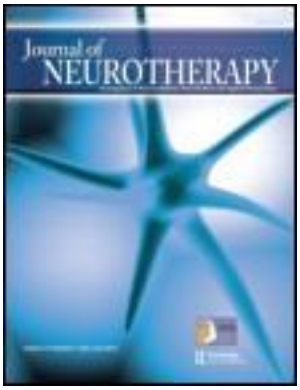

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Effects of Preparedness to Deceive on ERP Waveforms in a Two-Stimulus Paradigm

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Effects of Preparedness to Deceive on ERP Waveforms in a Two-Stimulus Paradigm

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SUMMARY. Stimulus salience, attentional capture, and working memory load have all been theoretically and experimentally linked to deception (Allen & Iacono, 1997; Boaz, Perry, Raney, Fischler, & Shuman, 1991; Dionisio, Granholm, Hillix, & Perrine, 2001; Stelmack, Houlihan, & Doucet, 1994). This study manipulated working memory load by truthful and deceptive response demands combined with congruent and incongruent response demands. Response demands were randomly presented across trials requiring attention shifting within each trial, and preparedness to deceive was systematically decreased across three ex-

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periments. Four waveforms were examined: an N2b occurring at 150-250 ms with an anterior maximum, a P3a occurring at 250-450 ms with an anterior maximum, an N4 occurring at 300-500 ms with an anterior and temporal maximum, and a P3b occurring at 500-700 ms with a parietal maximum. Results suggest that the processes of stimulus salience, attention shifting and resource allocation, long-term memory, and context updating are involved when individuals deceive.

KEYWORDS. Deception, response congruity, ERP, preparedness

An individual's preparedness to tell a lie may have profound effects on any detection of deception methodology, including those that measure behavior, the peripheral nervous system, or the central nervous system. In real-world situations there are three common latencies between the onset of preparation to deceive and the lie itself. Individuals may prepare and rehearse a lie for days, weeks, or even years before they tell it. In some structured interview scenarios, such as a polygraph exam, they may have several minutes to prepare a response between the time the question is asked and their deceptive response. However, in most situations, such as witness interrogation or medical malingering, a question is asked and respondents must spontaneously evaluate that question, determine whether or not they wish to lie, and then prepare to make a truthful or deceptive response. This study examines the last category of questions.

We measured event-related brain potentials (ERPs), electroencephalographic signals time-linked to a cognitive activity, in three sequential experiments that systematically manipulated preparedness to deceive. ERP methodology allows researchers to evaluate the patterns of cortical activity associated with specific cognitive tasks; because all responses are temporally linked to specific stimuli or responses, we can say with certainty that any cortical activity measured was generated in response to given stimuli. As such, the current ERP-based paradigm allows us to form conclusions about differences in cortical activation patterns between truthful and deceptive responses and between respondents who are prepared to deceive and those who are not. Some participants were more prepared to respond deceptively or truthfully (i.e., received more information from Stimulus 1) than other participants based on the condition to which they were assigned. The ERP waveforms generated in each condition and across studies were analyzed to determine the impact of variations in preparedness.

ERPs have previously been used to examine the neurocognitive processes associated with deception. Conflicting cognitive theories of the processes underlying deception have been developed based on the mechanisms known to elicit these potentials. Theorists argue that the process of deception may involve attentional capture (Allen & Iacono, 1997), working memory load (Dionisio, Granholm, Hillix, & Perrine, 2001; Stelmack, Houlihan, & Doucet, 1994), or perceived incongruity with semantic and episodic memory (Boaz, Perry, Raney, Fischler, & Shuman, 1991). Regardless of theoretical approach, however, four ERP waveforms have been associated with deception, the P3b, P3a, N2b, and N4.

P3b

The P300 (also known as the P3b), a large positive-going peak with a latency of 350-600 ms and a distribution whose maximum amplitude is at parietal sites and whose minimum amplitude is at anterior sites (Verleger, 1997), is by far the most frequently reported component of the four. It is typically studied in the context of the Concealed Information (CIT) oddball paradigm. This test consists of concealed information stimuli that occur infrequently eliciting a large P300, presented among a series of frequently occurring stimuli which do not involve concealed information and do not elicit a P300 (Allen, Iacono, & Danielson, 1992). When used in this type of paradigm, the P300 component of the ERP reliably and accurately indicates the presence of concealed knowledge (Allen & Iacono, 1997; Allen et al., 1992; Bashore & Rapp, 1993; Ellwanger, Rosenfeld, Sweet, & Bhatt, 1996; Farwell & Donchin, 1991; Rosenfeld, Ellwanger, & Sweet, 1995; Rosenfeld, Reinhart, & Bhatt, 1998; Rosenfeld, Sweet, Chuang, Ellwanger, & Song, 1996).

The spatio-temporal characteristics of the P300 observed in the CIT matches those of the P3b (Rosenfeld et al., 1999). The P3b is involved in many types of higher cortical functions including stimulus evaluation (Gevins, Cutillo, & Smith, 1995; Ruchkin, Johnson, Canoune, Ritter, & Hammer, 1990; Verleger, 1997), attention resource allocation (Comerchero & Polich, 1999), and updating of information held in working memory (Donchin & Coles, 1988; Ruchkin, Johnson, Canoune, & Ritter, 1990). Precisely which of these underlying processes are involved in deception is unclear, and in the CIT oddball task an often criticized confound of episodic memory further obscures interpretation (Allen & Iacono, 1997).

Because we removed the frequency related aspects of the task involved in a CIT that might impact the P300, we expected to see a suppression of the P300 amplitude related to the increased task demand of responding deceptively as opposed to truthfully. As the tasks became more difficult across experiments, we anticipated seeing greater suppression of the P3b across tasks.

P3a

Like the P3b, the P3a is elicited by an oddball paradigm. The term "P3a" is applied to an assortment of early components with anterior distributions, and the exact conditions necessary to evoke a P3a vary across paradigm and stimulus demands (Katayama & Polich, 1998). In one variant of the oddball, the three-stimulus paradigm, the P3a occurs in response to novel-infrequent stimuli presented in addition to "typical" oddball stimuli. This waveform can also be elicited by shifts in attention (Comerchero & Polich, 1999), switching from difficult to easy task demands (Comerchero & Polich, 1999; Harmony et al., 2000), and alerting (Katayama & Polich, 1998). In general, the waveform is characterized as a positive-going peak with an anterior distribution and a latency of 250-350 ms (Comerchero & Polich, 1999; Harmony et al., 2000; Spencer, Dien, & Donchin, 1999). Two ERP studies of deception reported an early positivity with spatio-temporal characteristics similar to the P3a (Matsuda, Hira, Nakata, & Kakigi, 1990; Pollina & Squires, 1998). Neither study involved the oddball paradigm. In the current study, an equal-probability paradigm was used, thereby eliminating the probability confound. Therefore we expected to see a larger P3a related to attentional allocation for truthful responding, than related to attentional allocation for deceptive responding. As the P3a is related to attention switching between two levels of task difficulty such as deception vs. truth, but not related to overall task difficulty, we did not expect to see any differences between the waveforms related to the tasks.

N2b

The N2b is elicited in attend conditions, and is associated with transient arousal and the orienting response (Loveless, 1983, 1986; Näätänen &

Gaillard, 1983). Therefore, decreased N2b latency is indicative of a lack of orienting toward task-related stimuli (Nordby, Hugdahl, Jasiukaitis, & Spiegal, 1999), and increased N2b latency is associated with the decline in attentional skill with age (Amenedio & Diaz, 1998). The N2b has also been associated with attention-switching tasks involving deception (Vendemia, 2003); individuals tend to orient to stimuli to which they must respond deceptively. We expected to see a larger N2b related to deceptive responses than truthful responses. As the tasks became more difficult and the response prompt became more relevant to the correct completion of the task, we expected to see greater N2b waveforms.

N4

The N4 component, a large negative-going peak at around 400 ms with maximum amplitude in anterior and temporal regions, is sensitive to semantic incongruity (such as in the sentence, "This morning for breakfast I had a nice hot cup of whiskers"). Researchers argue that deception represents an incongruity between internal truth and external response (Bashore & Rapp, 1993). The N4 has been elicited by the possession of concealed knowledge in tasks involving false sentence completions (Boaz et al., 1991) and in a two-stimulus target detection task (Matsuda et al., 1990). Bashore and Rapp (1993) suggest that the N4 is reactive to anomalies in semantic and episodic memory as well as to inconsistencies in language semantics. In a two-stimulus task, the N4 was not found to be sensitive to deception, but was sensitive to response congruity with the second stimulus (Stelmack, Houlihan, & Doucet, 1994; Stelmack, Houlihan, Doucet, & Belisle, 1994).

The current study used a two-stimulus paradigm in which the first stimulus consisted of a statement and the second of a "true" or "false" prompt. Similar to studies by Stelmack and colleagues (Stelmack, Houlihan, & Doucet, 1994; Stelmack, Houlihan, Doucet, & Belisle, 1994), participants were asked to evaluate the first stimulus and, based on its truth-value, agree or disagree with the second stimulus. The paradigm was based on the Directed Lie Test (DLT), which is a reliable and valid measure of deception (Honts & Raskin, 1988; Raskin, Kircher, Horowitz, & Honts, 1989). In the DLT, participants are instructed to tell lies to specific questions, such as responding "No" to the question, "Have you ever exceeded the speed limit?"

The paradigm was designed to control for a number the factors known to affect ERP signals. Attentional capture was manipulated by the use of an attention-switching paradigm, while multiple levels of task difficulty assessed working memory load. Using sentence evaluation instead of denial of recall-based information eliminated the issue of episodic memory. Additionally, the equiprobable nature and random presentation of the deceptive and truthful conditions allowed the effects of attention and workload to be parametrically equated on a trial-by-trial basis independent of stimulus presentation probability, which controls for and eliminates potential probability confounds.

Because we used an attention-switching paradigm, a P3a was expected. In addition, we expected that the amplitude of both the P3a and P3b would be suppressed for deceptive responses relative to truthful responses because of the increased task demand of responding deceptively as opposed to truthfully (Pollina & Squires, 1998; Vendemia, 2003). Based on previous findings (Vendemia, 2003), we hypothesized an increased latency of the N2b in deceptive conditions relative to truthful conditions. However, evidence from the same study suggesting that the N4 is not correlated with deception led us to predict that the N4 would not discriminate between deceptive and truthful conditions, but that it would be affected by congruity.

We expected that reduced preparedness to deceive would increase the salience of Stimulus 2. As the salience of this stimulus item increased, so too would attentional resource allocation. The ERP effects of this, we hypothesized, would be suppressed P3a amplitude (Wilson, Swain, & Ullsperger, 1998) and increased P3b amplitude (McGarry-Roberts, Stelmack, & Campbell, 1992; Picton, 1992; Kok, 2001; Vendemia, 2003). Based on as yet unpublished results in our laboratory, we expected P3a and P3b latencies to decrease with increasing preparedness to deceive.

METHOD

Three studies of increasing difficulty were conducted to examine ERP waveforms in relation to deception, response congruity, and preparedness to deceive. Participants were asked to evaluate sentences (Stimulus 1) that were either true or false, compare those evaluations with a second stimulus (Stimulus 2; either "true" or "false"), and respond truthfully or deceptively. In Experiment 1, all the information needed for participants to correctly complete the task was presented within Stimulus 1. That is, both congruity and deception (BCD) were predictable from Stimulus 1. In Experiment 2, information regarding deception was available from the first stimulus, but information regarding response congruity was not available until the onset of Stimulus 2. That is, only deception (OD) was predictable from Stimulus 1. Experiment 3 reduced the predictive value of Stimulus 1 to zero (i.e., neither congruity nor deception were predictable; NCD), increasing the amount of information to be absorbed from Stimulus 2. This resulted in greater salience and workload demands across the experiments, as shown in Table 1.

Experiment 1

Participants. Participants were 34 undergraduate students recruited from the University of South Carolina student population. Demographics for all three experiments are given in Table 2. All were right handed and had normal or corrected to normal vision with no known color impairments. Participants were also screened for a variety of neurological and medical disorders and were asked to avoid drugs, alcohol, and caffeine for 24 hours preceding the experiment. Participants received course credit for their participation.

Task. Each participant sat in a comfortable chair approximately 122 cm from a 29-inch color video computer monitor (NEC Multisync XM29) displaying at 1280 horizontal and 1024 vertical pixels.

The two-stimulus paradigm involved the pairing of a first stimulus, a statement which participants evaluated, and a second stimulus ("true" or "false") to which they responded. Each first stimulus was drawn from a series of 60 sentences involving declarative knowledge that were designed to be easily verified as true or false (e.g., "I am human"). Several examples of the sentences used are shown in Table 3. These stimuli were derived from a set of 100 short, easy to understand sentences that had been pre-tested with an undergraduate sample at the University. Raters were asked to decide whether each sentence was true or false. Only those items unanimously rated as "true" or "false" during pre-testing were retained for the experiments.

Sentence presentation lasted 2500 ms, followed by a 750 ms fixation point, then a second stimulus of 2500 ms duration (see Table 1). Participants responded to the second stimulus by pressing a key to indicate whether it agreed or disagreed with their answer to the first stimulus. This procedure is similar in nature to that used by Rosenfeld et al. (1996), a modified forced-choice procedure to detect malingering.

Participants were required to make a congruent response (i.e., "agree") on 50% of the trials and an incongruent response (i.e., "disagree") on the other 50% of the trials. Additionally, participants were cued by stim-

TABLE 1. Experimental Procedure, Stimulus 1 Predictability, and Anticipated Responses

Experiment/Condition	Stimulus 1 (2500 ms)	Fixation (750 ms)	Stimulus 2 (2500 ms)	Correct Response
Experiment 1 (BCD)	Predicts deception and congruity			
Congruent Truthful	The grass is red	+	False	Agree
Congruent Deceptive	**The grass is red**	+	True	Agree
Incongruent Truthful	The grass is green	+	False	Disagree
Incongruent Deceptive	**The grass is green**	+	True	Disagree
Experiment 2 (OD)				
Base True	Predicts deception			
Congruent Truthful	The grass is green	+	True	Agree
Congruent Deceptive	The grass is green	+	False	Agree
Incongruent Truthful	The grass is green	+	False	Disagree
Incongruent Deceptive	The grass is green	+	True	Disagree
Base False				
Congruent Truthful	The grass is red	+	False	Agree
Congruent Deceptive	The grass is red	+	True	Agree
Incongruent Truthful	The grass is red	+	True	Disagree
Incongruent Deceptive	The grass is red	+	False	Disagree
Experiment 3 (NCD)	Predicts nothing			
Base True				
Congruent Truthful	The grass is green	+	True	Agree
Congruent Deceptive	The grass is green	+	False	Agree
Incongruent Truthful	The grass is green	+	False	Disagree
Incongruent Deceptive	The grass is green	+	True	Disagree
Base False				
Congruent Truthful	The grass is red	+	False	Agree
Congruent Deceptive	The grass is red	+	True	Agree
Incongruent Truthful	The grass is red	+	True	Disagree
Incongruent Deceptive	The grass is red	+	False	Disagree

Note. In this example, *BLUE* text cues the participant to respond truthfully, while **RED** text cues the participant to respond deceptively. This designation was counterbalanced throughout the experiments. The key difference between Experiments 1 and 2 is that in Experiment 1 Stimulus 1 predicts both deception and congruity, whereas Stimulus 1 in Experiment 2 predicts only deception. Unlike the first stimulus in Experiment 1, the first stimulus in Experiment 2 (e.g., “The grass is green”) could be followed by a Stimulus 2 value of “True” or “False,” thus changing the correct response. Therefore, Stimulus 1 does not predict congruity.

TABLE 2. Demographic Information for Participants Across the Three Studies (n = 84)

	Sex		Age		
	Men (n)	Women (n)	Range	M	SD
Experiment 1 (n = 34)	19	15	18-39	21	4.09
Experiment 2 (n = 27)	11	16	18-24	20	1.89
Experiment 3 (n = 23)	8	15	18-25	20	1.85
Total (n = 84)	38	46	18-39	20	3.05

TABLE 3. Examples of Sentences Used in the Three Experiments

Base Truth Value	Stimulus Sentence
True	The grass is green.
	South Carolina is in the United States.
	Ducks spend most of their time in the water.
	A piano is a musical instrument.
	Poodles are dogs.
False	Snakes have 13 legs.
	People are born wearing clothes.
	The slowest runner always wins the race.
	Cupcakes are healthier than salad.
	President George Washington cleans my kitchen.

ulus color to respond deceptively on 50% of the trials and truthfully on the other 50%. The stimuli were presented in red or blue. Participants were randomly assigned color cued deception. Deceptive and truthful trials were randomly presented. Furthermore, the color of Stimulus 1 always predicted Stimulus 2 (i.e., the color of Stimulus 1 always matched the color of Stimulus 2). Thus, both congruity and deception (BCD) were predictable from Stimulus 1–the defining feature of Experiment 1. For example, when presented with a red Stimulus 1, a given participant would always receive a red “true” as Stimulus 2. The relationship between color and Stimulus 2 was counterbalanced across participants.

As shown in Table 1, when participants were color cued to be truthful and the second stimulus provided an accurate description of the truth state of the first stimulus, they responded by pressing “agree.” We labeled this “congruent truthful” to denote that the respondent truthfully indicated that the second stimulus was congruent with their answer to the first stimulus. When color cued to be truthful and the second stimulus did not provide an accurate assessment of the truth state of the first stimulus, they responded by pressing "disagree" (incongruent truthful). When color cued to be deceptive and the second stimulus provided an inaccurate answer, they responded "agree" (congruent lie). Finally, when color cued to be deceptive but the second stimulus accurately described the truth state of Stimulus 1, they responded "disagree" (incongruent lie). This resulted in four experimental conditions: congruent truthful, congruent lie, incongruent truthful and incongruent lie (CT, CL, IT, IL). ERP data were collected on three blocks of 60 randomized trials each. This resulted in 45 trials of each trial type.

Procedure. Participants arrived at the lab on the day of the experiment and were familiarized with the research procedure before signing the consent form. They practiced on a pencil and paper measure that included all stimuli used in the study. Following the paper task, participants were seated in front of the monitor, verbally instructed on the use of the response box, and received additional computer-based practice to train them to respond within the allowed response window of 2500 ms. The computer-based practice consisted of 12 items from the larger block of questions, constrained so that it contained equal numbers of CL, CT, IL, and IT questions. Participants were required to attain a 67% accuracy level on each of the trial types in order to begin the experiment. Records of the number of practice block repetitions required and the time to completion were not kept, but six participants were disqualified from further participation because they could not achieve the 67% correct threshold. During the experiment, participants initiated each trial by key press. They were instructed to rest during the period between trials if they felt tired. During the rest period, the stimulus presentation screen reminded participants of the response box instructions.

Experiment 2

In the second study, response congruity was not predictable from cues in Stimulus 1. In other words, Stimulus 1 was colored either red or blue, but Stimulus 2 did not predict congruity. Thus, participants could utilize the color of Stimulus 1 to prepare to lie or tell the truth, but could not predict whether they would do so by agreeing or disagreeing.

Participants. Participants were 27 undergraduate students (see Table 2) recruited using the same procedures as in Experiment 1.

Task. The task was identical to the task in Experiment 1 with one exception. In the second study, the first stimulus only predicted deception, not response congruity. Thus, participants would not be able to determine the specific response until the onset of the second stimulus. As in all three experiments, deception cue color was randomly assigned.

Procedure. The procedure was identical to Experiment 1.

Experiment 3

In the third study, Stimulus 1 sentences were colored black, offering no predictive value for either response congruity or the truth-value of the response. Participants could prepare neither to respond deceptively or truthfully nor to agree or disagree in response to the stimuli.

Participants. Participants were 23 undergraduate students (see Table 2) recruited using the same procedures as in Experiment 1.

Task. The task in Experiment 3 differed from the task in the earlier experiments in two ways. In the first study, the first stimulus predicted both deception and response. In the second study, the first stimulus only predicted deception. In the third study, the first stimulus predicted neither deception nor congruity (see Table 1). Thus, participants would not be able to predict the nature of the response until the onset of the second stimulus. In addition, the presentation time of the second stimulus was increased to 3000 ms to allow participants enough time to respond. This modification was based on pilot testing, which indicated that participants in this more difficult experiment required more time to generate the correct response.

Procedure. The procedure was identical to Experiments 1 and 2.

Recording and Segmenting of EEG for ERP. ERPs in truthful and deceptive conditions were recorded using a 128 channel "Geodesic Sensor Net" with the EGI system (Electrical Geodesics, Inc., Eugene, OR; Tucker, Liotti, Potts, Russell, & Posner, 1994). The net was positioned according to its anatomically marked locations. Sites on this cap can be interpolated to those of the International 10-20 system (Luu & Ferree, 2000; Srinivasan, Tucker, & Murias, 1998). The signal was referenced to the vertex. Impedances were kept below 100 kΩ, and the signal was amplified with the EGI "NetAmps" that consist of high-impedance amplifiers and a PowerPC-based computer system. The EGI "NetStation" computer program was used to control zero and gain calibrations for each participant, impedance calibration, A/D sampling (250 Hz), and

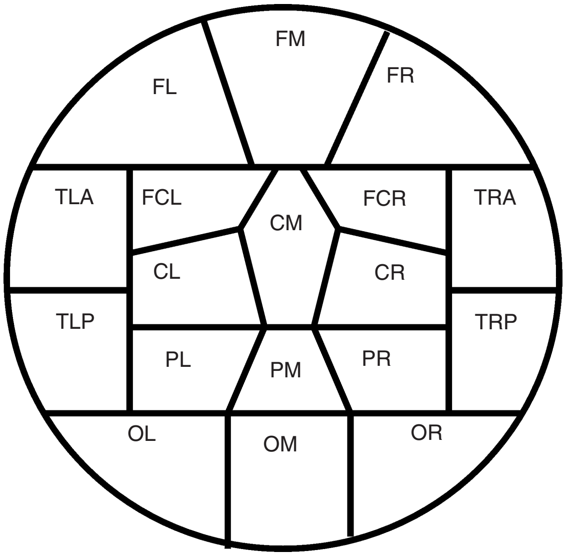
EEG data storage. Band-pass filters were set at 0.1 to 100 Hz with 20K amplification.

A second computer was time-synchronized with the PowerPC running the NetStation computer program so that time and trial information was stored with the EEG recordings. The data were segmented offline using a 600 ms baseline and 1000 ms post-stimulus period. Electrodes that exceeded a 70 μV threshold were eliminated from further analysis. Trials that contained more than 10 "bad" electrodes, an eye blink, or an incorrect response to the second stimulus were eliminated. The cut-off 10 "bad" electrodes (7.7% of the total electrodes), were 2.7% more of the data than the 5% total bad electrode limit suggested by Picton et al., (2000). However, in line with their suggestions, electrodes up to the 7.7% cut-off were interpolated using spherical splines. After this stage of data analysis any participant with more than 20 trials (11%) of the experimental trials rejected for any reason were eliminated from further analyses. This strategy was based on the minimum number of trials necessary to develop an observable ERP from the averaged data. Five of the original 84 participants were eliminated through these procedures. For the rest of the participants missing data were replaced using the averaged potential of the five closest electrodes. Data were re-referenced to a mastoid reference offline, baseline corrected using the 100 ms prestimulus interval and filtered from 1 to 30 Hz.

RESULTS

A series of 2 × 2 × 3 mixed measures ANOVAs (Deception × Congruity × Predictability) compared the amplitudes and latencies of four waveforms (i.e., N4, N2b, P3a, and P3b) across regions specific to the distribution of each waveform (see Figure 1). All significant tests were followed with appropriate post-hoc analyses, and only significant findings are reported. Figure 2 shows a sample topographic distribution for each waveform. Waveforms were identified according to the following pre-selected windows: N4, 300-500 ms; N2b, 150-250 ms; P3a, 250-450 ms; P3b, 500-700 ms. Findings will be discussed relative to predictability condition: Experiment 1–both congruity and deception predictable (BCD), Experiment 2–only deception predictable (OD), and Experiment 3–neither deception nor congruity predictable (NCD).

FIGURE 1. Eighteen regions of 6 averaged electrodes each based on the 10-20 system. FL, FM, FR, FCL, and FCR represents frontal left, middle, right, central left, and central right. TLA, TLP, TRA, and TRP represents temporal, left anterior, left posterior, right anterior and right posterior. CL, CM, and CR represents central left middle and right; PL, PM, and PR represents parietal left, middle, and right, and OL, OM, and OR represent occipital left, middle, and right.

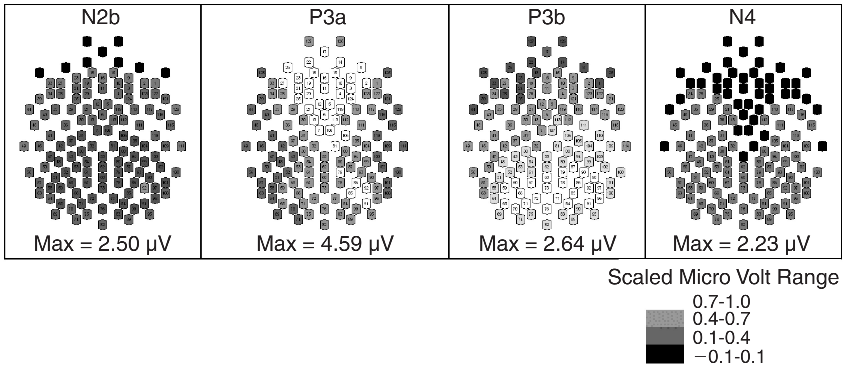


N2b

Mixed ANOVAs for the N2b amplitude and latency were conducted on anterior temporal, frontal, and central regions–the regions specific to the distribution of the N2b. There was a main effect of predictability at the left anterior region such that N2b latencies were longest in the NCD condition and shortest in the BCD condition [$F(2, 81) = 3.38, p = .04, \eta^2 = .08$].

There were significant latency two-way interactions between predictability and deception in the left frontal [$F(2,81) = 3.27$, $p = 0.04$, $\eta^2 = .08$] and left central [$F(2,81) = 3.99, p = 0.02, \eta^2 = 0.09$] regions. As can be seen in Figure 3, N2b latencies for truthful and deceptive responses were not significantly different in BCD. In OD at the left frontal region there was a trend towards N2b latency being longer for truthful than deceptive responses. In the left central region in BCD and OD the N2b la-

FIGURE 2. Illustrative topographic distributions for the N2b (CT, OD), P3a (IL, OD), P3b (IL, 2200), and N4 (CL, NCD).



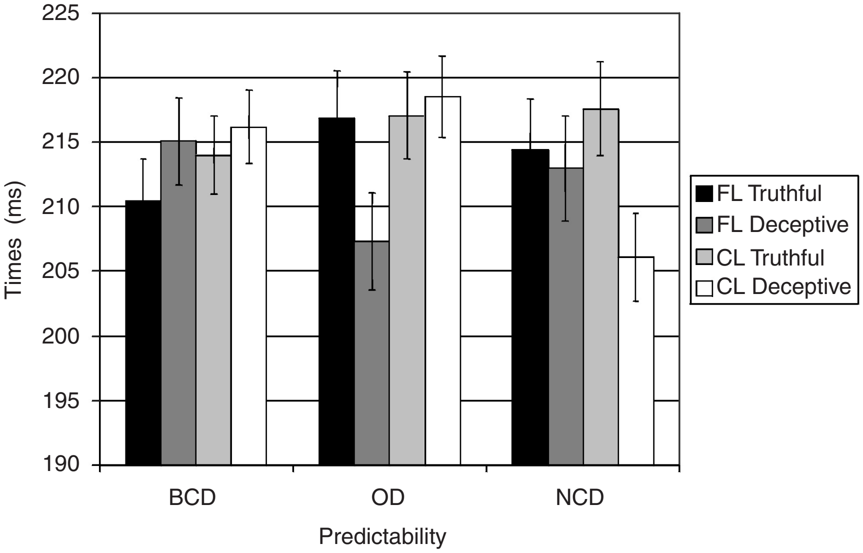
tency did not differ between response types, but in NCD the latency for truthful responses was longer than for deceptive responses.

P3a

Mixed ANOVAs for the P3a were conducted in the frontal and central regions. As Figure 4 shows, in the middle central region, the amplitude of the P3a was greater when participants responded truthfully $F(1, 81) = 8.59$, $p = .005$, $\eta^2 = .11$. In the frontocentral central region, there was a trend for the latency of the P3a to be shorter for truthful responses (M = 378.94 ms, SE = 1.91), than for deceptive responses [$M = 383.61$, $SE = 1.86$; $F(1,81) = 3.83$, $p = .054$, $\eta^2 = .05$]. In the right frontocentral region, the latency of the P3a differed with predictability $F(2,81) = 3.35$, $p = .041$, $\eta^2 = .05$ such that the latency of the P3a was longest for the OD group and shortest for the BCD group.

There were no two-way interactions, but a three-way interaction occurred in the right frontocentral region [$F(2,81) = 4.02$, $p = .022$, $\eta^2 = .11$]. As seen in Figure 5, the latency of truthful responses was longer than deceptive response in the BCD group. In the OD group, truthful responses were associated with a longer P3a latency than deceptive responses only when participants agreed, while in the NCD group truthful responses had a longer latency than deceptive responses only when participants disagreed.

FIGURE 3. Latency of the N2b for truthful and deceptive responses at left frontal and left central regions for the BCD, OD, and NCD groups.



P3b

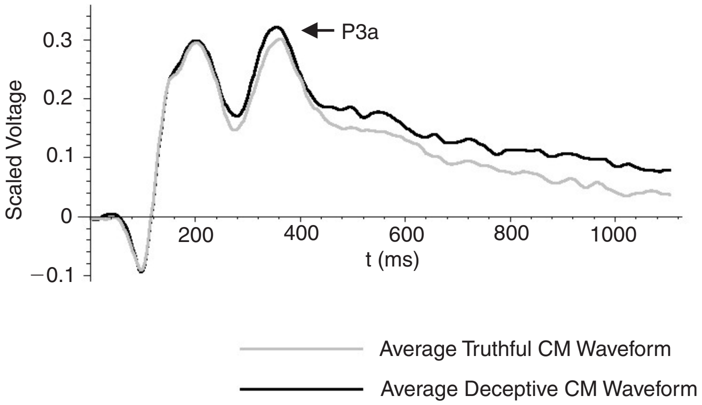
Mixed ANOVAs for the P3b were conducted for the parietal, central, and frontocentral regions. Waveforms for all conditions are shown at the parietal region in Figure 6.

In the frontocentral region, the P3b amplitude for deceptive responses ($M = 2.59$, $SE = 0.18$) was significantly smaller than for truthful responses [$M = 2.75$, $SE = 0.19$; $F(1,81) = 4.23$, $p = 0.04$, $\eta^2 = 0.05$].

Across central and parietal regions, P3b amplitude was greater when participants agreed than when they disagreed, as shown in Table 4. The magnitude of this difference was largest in the mid-parietal region ($M =$ 3.34 µV, $SE = .23$ vs. $M = 2.93$ µV, $SE = .20$). P3b latency in these regions was longer when participants agreed than when they disagreed, and this difference was similarly largest in the mid-parietal region ($M =$ 655.81 ms, $SE = 3.84$ vs. $M = 629.99$ ms, $SE = 4.62$ ms).

There were three-way interactions involving the latency of the P3b in the middle and right central and parietal regions (Table 4). The latency difference between truthful responses and deceptive responses remained constant between BCD and OD conditions for both agree and dis-

FIGURE 4. Waveforms for truthful vs. deceptive responses at the middle central region for all participants (n = 81).



agree responses. In the NCD condition, however, the latency difference increased when participants agreed and decreased when they disagreed (see Figure 7).

N4

Mixed ANOVAs on N4 latency and amplitude were conducted for the anterior temporal, frontal, and central regions (Table 5). Anterior Temporal N4 waveforms for all conditions are shown in Figure 8. There were main effects for deception in the right and left anterior temporal regions. In the right anterior temporal region, the amplitude for truthful responses ($M = -1.40$ μV, $SE = 0.06$) was larger than for deceptive responses ($M = -1.27$ μV, $SE = 0.05$). In the left anterior temporal region, the latency for truthful responses ($M = 443.42$, SE = 3.41) was shorter than for deceptive responses ($M = 450.91$, $SE = 3.35$).

There were interactions between congruity and deception for amplitude at the left and right frontocentral regions, right central region, and right posterior temporal region. As can be seen in Figure 8 (showing anterior temporal regions), the amplitude for IL was larger than IT in all regions, and CL amplitude was larger than CT amplitude in most regions. There were also two-way interactions for latency in the frontocentral and left central regions such that the latency for deceptive responses was greater than for truthful responses, and the difference in latency was much smaller for disagree than agree responses.

FIGURE 5. Event-related waveform at right frontal sites between all four response types for BCD, OD, and NCD groups.

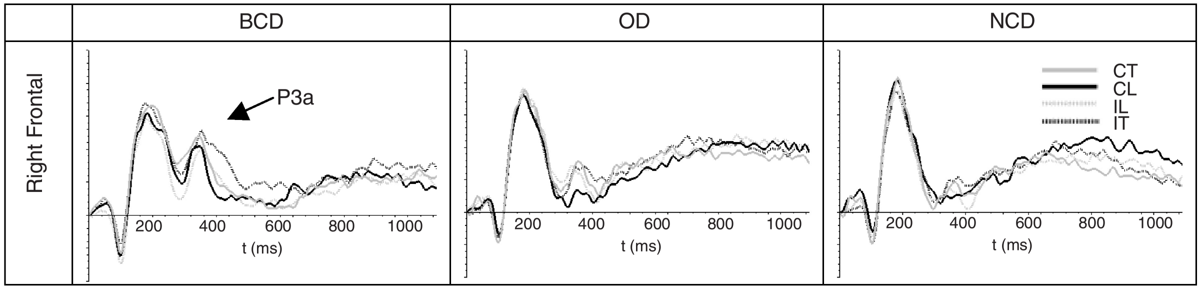


FIGURE 6. Event-related waveform at right frontal sites between all four response types for BCD, OD, and NCD groups..

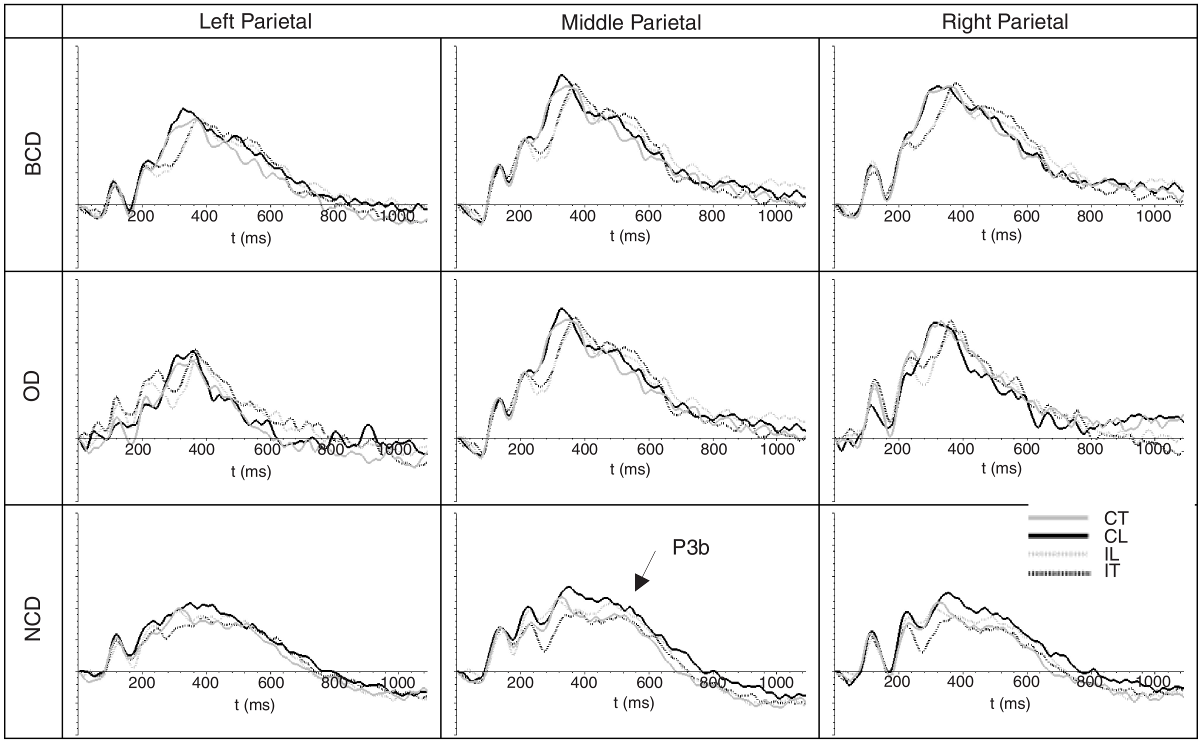
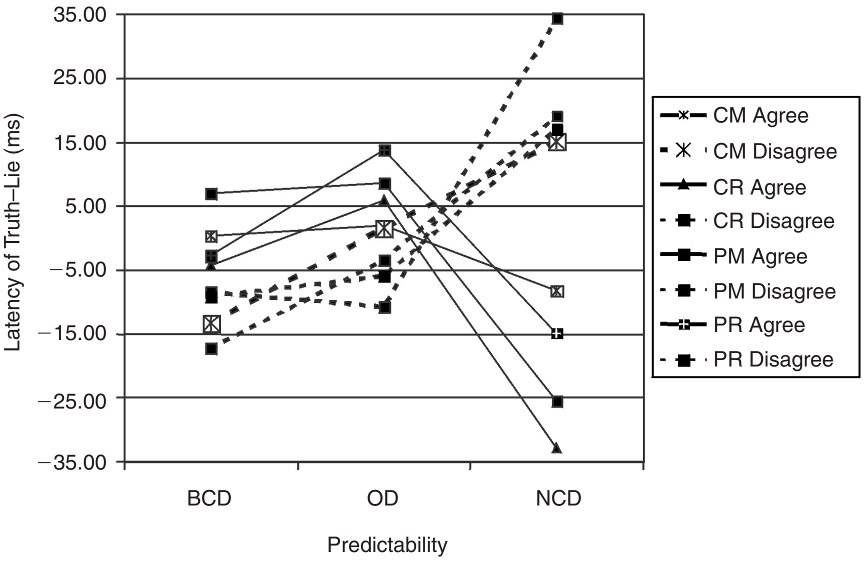


FIGURE 7. The difference in P3b latency between truthful and deceptive responses when participants responded by agreeing and disagreeing across levels of predictability.



There was an interaction in N4 latency between deception and predictability at the left temporal region such that the latency for truthful responses was smaller than for deceptive responses in the BCD and NCD conditions, but there was no difference in the OD condition.

DISCUSSION

Deception

As expected, the amplitude of the P3a was larger when participants responded truthfully as compared to deceptively. This is consistent with Comerchero and Polich's (1998) attention switching theory of the P3a, which suggests that the amplitude of the P3a is increased when individuals switch from more difficult to easier task demands. Additionally, we found that deception suppressed the amplitude of the P3b waveform regardless of preparedness to deceive. This is consistent with previous findings (Stelmack, Houlihan, & Doucet, 1994; Stelmack, Houlihan,

TABLE 4. Significant ANOVA Results (con × dec × pred) for the Amplitude and Latency of the P3b Waveform

Source	*df*	*F*	η^2	*p*
Amplitude				
FCL (dec)	1	4.23	0.05	0.04
PL (con)	1	5.39	0.06	0.02
CL (con)	1	9.76	0.11	0.00
CR (con)	1	17.56	0.18	0.00
CM (con)	1	12.57	0.13	0.00
PM (con)	1	10.44	0.11	0.00
PR (con)	1	9.16	0.10	0.00
FCR (con × dec)	1	5.70	0.07	0.02
FCL (con × pred)	2	3.63	0.08	0.03
CL (dec × pred)	2	3.60	0.08	0.03
Latency				
PL (con)	1	14.58	0.15	0.00
PM (con)	1	46.90	0.37	0.00
PR (con)	1	28.96	0.26	0.00
CR (con)	1	43.50	0.35	0.00
CR (pred)	2	3.33	0.08	0.04
PL (con × dec × pred)	2	6.00	0.13	0.00
PM (con × dec × pred)	2	11.23	0.22	0.00
PR (con × dec × pred)	2	4.20	0.09	0.02
CR (con × dec × pred)	2	12.18	0.23	0.00

Note. Condition abbreviations: Con = Congruity, Dec = Deception, Pred = Prediction. Error *df* = 81.

Doucet, & Belisle, 1994; Vendemia, 2003) and suggests that deception is cognitively challenging no matter how prepared the respondent is to deceive.

Deception also suppressed the N4 amplitude, contrary to our predictions. While it is believed that the N4 is related to semantic incongruity, it has been elicited by the possession of concealed knowledge in sentence completion tasks involving false sentence completions (Boaz et al., 1991) and in a two-stimulus target detection task (Matsuda et al., 1990). One can conceive of deception as an incongruity between the internal truth and the external response (Bashore & Rapp, 1993), an interpretation that is supported by this finding.

TABLE 5. Significant ANOVA Results (con × dec × pred) for the Amplitude and Latency of the N4 Waveform

Source	*df*	*F*	η^2	*p*
Amplitude				
TRA (dec)	1	5.32	0.06	0.02
FCL (con × pred)	2	4.67	0.10	0.01
FCR (con × dec)	1	5.12	0.06	0.03
TRP (con × dec)	1	4.08	0.05	0.05
CR (con × dec)	1	6.63	0.04	0.18
CM (con × dec × pred)	2	4.19	0.09	0.02
Latency				
TLA (dec)	1	7.35	0.08	0.01
FCL (con × pred)	2	5.35	0.12	0.01
CL (con × pred)	2	5.56	0.12	0.01
TLA (dec × pred)	2	4.43	0.10	0.02

Note. Condition abbreviations: Con = Congruity, Dec = Deception, Pred = Prediction. Error *df* = 81.

Congruity

Significant main effects were found for the effect of response congruity on the centrally- and parietally-generated P3b, such that P3b amplitude was suppressed and the latency was generally decreased for incongruous responses versus congruous responses. The same effect was found for the N2b in mid and right parietal and occipital regions.

Predictability

As predicted, reduced preparedness to deceive led to suppressed P3a amplitude and decreased P3a latency. We also found that decreasing predictability led to shorter P3b latencies. However, contrary to our predictions, we found that as predictability decreased, P3b amplitude increased and N2b latency increased. These findings suggest that reducing preparedness to deceive does in fact increase the salience of the Stimulus 2 in the two-stimulus paradigm. As more information must be drawn from this stimulus, the attentional resources allocated to it must necessarily increase, as indicated by the effects of predictability on the P3a. Concurrent with or following this period of focused attention, the participant must orient to the information presented in the second stimulus, a task made more important as preparedness to deceive decreases. This is reflected in the variations in N2b latency, which increased as predictability decreased. Just as the act of formulating a deceptive response is more cognitively challenging than generating a truthful response, so too is generating any response with decreasing preparedness. That is, as participants receive less information from Stimulus 1, more information must be gleaned from Stimulus 2, a decision to deceive or tell the truth must be made, an answer formulated, and a response completed.

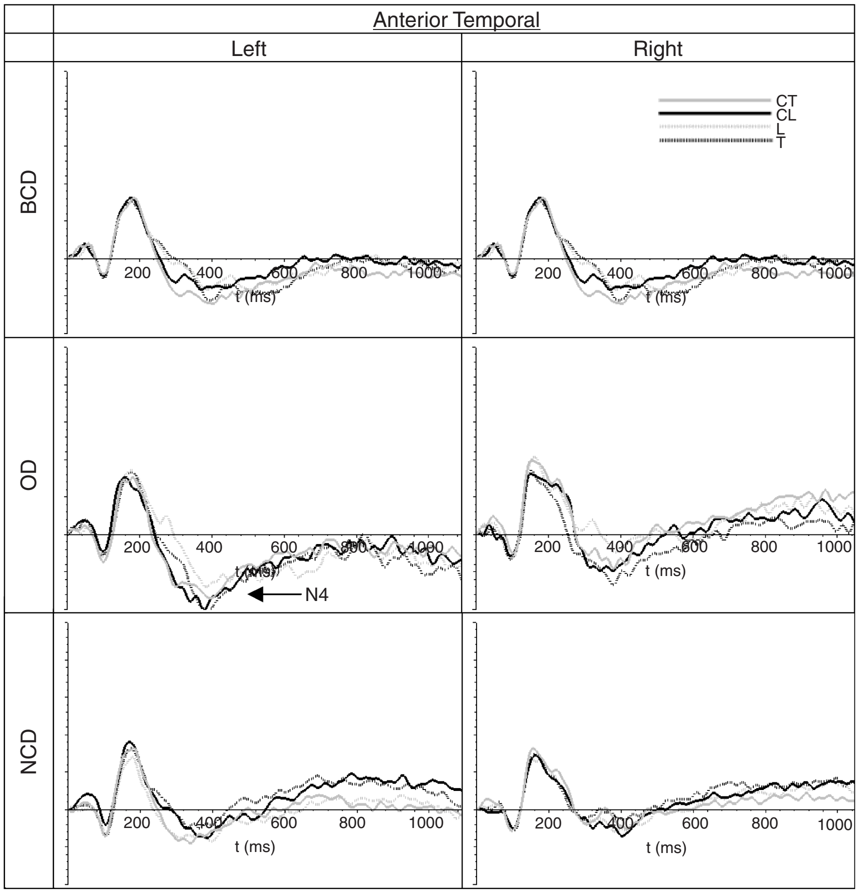
CONCLUSIONS

Previous theories of deceptive responding have postulated attention, working memory load, and congruity as sources of ERP variation between deception and truth. This study suggests that processes related to all three theories underlie deception. Particularly when studying brain waves associated with deception, it is extremely important to control for variables that may affect salience and workload, as these two processes have conflicting effects on ERPs, particularly the P3b.

Individuals in each experiment shifted their attention to allocate resources to specific task demands, which themselves exerted separate effects for deception and congruity. The P3a, with neuronal sources in the anterior cingulate, seems to result from orienting towards task-related stimuli, such as congruity and deception (Vendemia, 2003). It is possible that the inherent incongruity of deception is also attended to at this time, reflected in the effects of deception on the P3a.

Following that initial attentional response, additional processing of congruity occurs across multiple regions of the frontal and temporal lobes, affecting the N4. The subsequent P3b engages decision-making processes and response selection. Workload associated with the additive effects of deception and congruity also suppressed the amplitude of the P3b, but as the salience of the second stimulus increased the pattern of amplitude suppression became less defined. Stimulus salience, manipulated by predictability, exerted a generalized impact on the N2b. The pattern of the N2b, related to stimulus salience, the P3a, related to orienting and attention shifting, the N4 related to comparison with internal semantic truth, and P3b related to ongoing workload and decision form a series of processes that are involved in deceptive processing.

FIGURE 8. Event-related waveforms in the left and right anterior temporal regions between all four response types for BCD, OD, and NCD groups.



We would anticipate that these findings are potentially useful in a variety of settings in which deception could occur. Because of the flexibility inherent in ERP-based paradigms, this methodology has possible applications in criminal investigations, terrorism prevention, and the detection of clinical malingering. Vendemia and Buzan (2004) utilized a similar two-stimulus paradigm to successfully identify more than 86% of "guilty" participants in a mock-crime experiment. Question sets can also be designed to evaluate terrorism-related guilt: connections to known terrorists, details of possible attacks, or involvement in past, present, or future terrorist plots. In clinical practice, questions can be formulated to detect patient attempts to fake the results of their evaluations. However, it should be noted that this methodology is not sufficiently developed for clinical use; data analysis is currently extremely time-intensive, taking up to a week to detect deception. With ongoing research, we expect to develop more real-time analysis tools that will provide clinicians with a quick and accurate tool to detect malingering within the time constraints of a medical or psychological evaluation.

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