The contribution of executive processes to deceptive responding

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Abstract

We measured behavioral responses (RT) and recorded event-related brain potentials (ERPs) when participants made truthful and deceptive responses about perceived and remembered stimuli. Participants performed an old/new recognition test under three instructional conditions: Consistent Truthful, Consistent Deceptive and Random Deceptive. Compared to Consistent Truthful responses, Consistent Deceptive responses to both perceived and remembered stimuli produced the same pattern of less accurate, slower and more variable responses and larger medial frontal negativities (MFN). The MFN is thought to reflect activity in anterior cingulate cortex, a brain area involved in monitoring actions and resolving conflicting response tendencies. The Random Deceptive condition required participants to strategically monitor their long-term response patterns to accommodate a deceptive strategy. Even compared to the Consistent Deceptive condition, RTs in the Random Deceptive condition were significantly slower and more variable and MFN activity increased significantly. MFN scalp distribution results revealed the presence of three different patterns of brain activity; one each for truthful responses, deceptive responses and strategic monitoring. Thus, the data indicate that anterior cingulate cortex plays a key role in making deceptive responses.

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1. Introduction

In the past decade, a number of investigators have used the event-related brain potential (ERP) to detect the presence of concealed information in humans. Investigators used a variety of approaches in which the well-documented inverse relation between the amplitude of the late positive component (LPC, also known as the P300) and stimulus probability was used to detect the presence of guilty knowledge. This was done both in persons concealing information related to a specific event (e.g., a crime) and in persons feigning memory loss (i.e., malingering). Studies in the former category demonstrated that the LPC can provide a useful index of the presence of concealed memories about specific events (e.g., Allen & Iacono, 1997; Farwell & Donchin, 1991; Johnson & Rosenfeld, 1992) and studies in the latter category showed that the LPC could reveal the true memory status of items in persons feigning amnesia (e.g., Allen, 2002; Allen, Iacono, & Danielson, 1992; Allen & Movius, 2000; Rosenfeld, Sweet, Chuang, Ellwanger, & Song, 1996; Rosenfeld et al., 1998, 1999). However, because the intent of these studies was to develop diagnostic tools to determine whether specific individuals were concealing knowledge of a crime or feigning amnesia for fraudulent purposes, they provided no information about the cognitive processes persons use when they conceal information.

Although the ERP technique has been used to investigate the neural basis of many aspects of cognition, no studies have been done to determine the nature of the cognitive processes used when persons are deceptive. In part, this may be due to the fact that there are many types of deception that vary considerably in their nature and complexity (Vrij, 2001). Furthermore, the cognitive operations that different people use for any given type of deception will likely depend on a variety of factors, including their personality and personal habits (e.g., how often they lie) and the circumstances surrounding the deception. In addition, other non-cognitive processes, such as those related to any emotional aspects of the deception, may also contribute to successful and unsuccessful deceptions.

To the best of our knowledge, there is no definition or conceptual framework that specifies the cognitive processes used when persons are deceptive (see Mitchell, 1986; Vrij, 2001 for reviews). To begin to determine which processes might be involved, we noted that at least some definitions can be interpreted as implicitly or explicitly dividing deception operations into two broad categories: (1) the cognitive processes used to formulate such factors as the rationale, intent and strategies relevant to a deception and, (2) the...
cognitive processes used to execute the deceptive motor response or act (cf. Furedy, Davis, & Gurevich, 1988). For convenience, we will refer to these as the intent and action stages of deception, respectively. An important and as yet unknown aspect of deception is the question of whether the processes used for the intent and action components draw on deception-specific processes or on more general-purpose processes that are also used in other aspects of cognition. If this latter view of deception were upheld, it would be compatible with the conclusions about autonomic nervous system function that there is no “specific lie response” or other unique autonomic response pattern associated with deception (e.g., Ben-Shakhar & Furedy, 1990).

It is important to point out that our proposed framework is tentative and meant to provide a starting point for specifying the processes involved in deception. Thus, there may well be additional cognitive processes that play important roles in the full spectrum of deceptive behavior. Moreover, an important aspect of deception-related processing not contained in this conceptualization is the extent to which emotional processes are associated with the intent and action stages of deception. For example, Vincent and Furedy (1992) found increased galvanic skin responses (GSR), a measure of autonomic nervous system activity, related to the emotional aspects of deception. However, it is not known whether this GSR activity reflected processing related to the intent or action processing stages, or both.

In our conception of deception, executive control processes play an essential role in a person’s ability to accurately execute deceptive responses. Executive processes are a term used to describe a variety of cognitive functions that work separately and in concert to control and coordinate the selection and execution of willed actions. Consequently, these processes are believed to constitute a fundamental aspect of a person’s ability to interact successfully with the environment in all situations. For example, it is generally thought that executive processes help to control actions by providing the means to monitor and resolve response conflicts whenever interference arises from competing information streams or when there is competition between alternative responses (e.g., Botvinick, Nystrom, Fissell, Carter, & Cohen, 1999; Carter et al., 1998; Gehring & Knight, 2000; Luu, Flaisch, & Tucker, 2000). Executive processes are also involved in inhibiting unwanted responses, as well as for detecting and inhibiting erroneous responses (e.g., Falkenstein, Hohnsbein, & Hoormann, 1991; Falkenstein, Hohnsbein, & Hoormann, 1994; Falkenstein, Hohnsbein, & Hoormann, 1994; Falkenstein, Hohnsbein, Christ, & Hohnsbein, 2000; Gehring, Goss, Coles, Meyer, & Donchin, 1993; Holroyd & Coles, 2002). Finally, executive processes are also used in dual task situations when it is necessary to coordinate and flexibly allocate the use of cognitive resources between tasks (e.g., Turk& Swick, 1999). In sum, it is via executive processes that a person can execute controlled and coordinated actions that conform to their overall plans and goals.

The importance of executive processes to deception is evident; regardless of the nature and extent of the cognitive and emotional processes that precede and accompany a decision to deceive, all deceptions ultimately require the execution of a response that is incompatible with the truth. It follows, therefore, that all successful deceptions depend on the use of executive control processes for the accurate resolution of the conflict between the tendency to make the pre-potent truthful response and the need to make a conflicting response. Hence, executive processes would be responsible for inhibiting the truthful response from being made inadvertently, thereby negating the deception. In addition, falsifying a response means that the deceptive person must also select a response that is incompatible (i.e., conflicts) with the truth and execute this deceptive response. Therefore, executive processes should play a greater role for deceptive responses compared to truthful responses. We note that, in terms of resolving conflicting response tendencies, at least this aspect of deception seems little different from what must be accomplished in other situations that involve response conflict. We expected, therefore, that the executive processes required to carry out a successful deception were likely to be the same as those used generally when pre-potent responses must be inhibited and incompatible responses executed.

Note that we are not maintaining that other processes are not important for deceptive responses. Rather, we hypothesized that certain executive processes are used whenever one makes an incompatible response. It should also be pointed out that the deceptive person must initially perform all the usual task- and response-related processes necessary to identify the truthful response before performing the extra processes required to inhibit the tendency to make this pre-potent response and select and execute the deceptive response. It follows that this additional deception-related processing would be overlain on those processes required to make truthful responses, thereby creating an additional processing load.

In recent years, researchers have been interested in the control processes used when responses are selected from competing alternatives and when erroneous responses need to be detected and corrected. Typically, response conflict has been induced by manipulating perceptual factors in such a way that one aspect of a stimulus suggests one particular response while another aspect of the same stimulus suggests a different, competing response. For example, in the Stroop task, participants see color words (e.g., “red”) printed in different colored inks (e.g., blue) and must respond by naming the color of the ink in which a word is printed while ignoring the response indicated by the word itself. Such perceptually-based response conflicts, which can be seen as analogous with the conflict between truthful and deceptive responses, typically affect task performance by reducing response accuracy and slowing response speed (e.g., Carter et al., 1998; Casey et al., 2000; Scheffers & Coles, 2000). Studies of brain activity using functional magnetic
resonance imaging (fMRI) have shown that an area of the medial frontal lobes, the anterior cingulate cortex (ACC), is active in a variety of situations in which stimuli create either conflicting response tendencies or uncertainty about the identity of the proper response (Barch, Braver, Sabb, & Noll, 2000; Botvinick et al., 1999; Carter et al., 1998, 2000; Casey et al., 2000; MacDonald, Cohen, Stenger, & Carter, 2000). For example, increased blood flow in the ACC has been shown to reflect the degree of response conflict, rather than the degree of stimulus conflict or general task difficulty (Van Veen, Cohen, Botvinick, Stenger, & Carter, 2001). In addition, the ACC has been found to be active in word recognition paradigms (e.g., Henson, Shallice, & Dolan, 1999; Saykin et al., 1999; Wagner, Desmond, Glover, & Gabrieli, 1998), a finding that presumably reflects the inherent conflict regarding the correct categorization of items as known or not. Further, the need to inhibit responses has been found to activate areas of the ACC different from those involved in error detection and correction (Garavan, Ross, Murphy, Roche, & Stein, 2002). Based on such results, the ACC has been hypothesized to be a multi-functional brain area that plays an important role both in controlling and monitoring a person’s actions when there are conflicts between intended and actual responses, as well as in inhibiting unwanted responses and signaling when a corrective response needs to be made (Botvinick et al., 1999; Carter et al., 1998; Luu et al., 2000).

Another measure of medial frontal activity is a negative component of the ERP that is elicited between 0 and 100 ms after a response and is largest over medial central-frontal scalp. Because this activity was initially found for error trials in tasks in which the stimuli elicited conflicting response tendencies (Falkenstein et al., 1991, 1994; Gehring et al., 1993), it was labeled the error-related negativity (ERN) or Ne (error negativity) (see Falkenstein et al., 2000 for a review). Subsequent studies have revealed that similar, albeit smaller, negativities were also elicited on correct trials (Gehring & Knight, 2000; Vidal, Hasbroucq, Grapperon, & Bonnet, 2000), particularly in situations when there was ambiguity about how stimuli should be categorized (Scheffers & Coles, 2000). Some investigators have suggested that the ERN arises from activity in neural circuits responsible for the executive processes involved in error correction and/or processes that oversee and monitor the participant’s actions (Falkenstein et al., 1991, 1994; Gehring & Knight, 2000; Gehring et al., 1993; Scheffers & Coles, 2000). Localization studies have consistently placed the neural generator of the ERN in the medial frontal lobes, in or near the ACC (Dehaene, Posner, & Tucker, 1994; Gehring, Hmie, & Nisenson, 2000; Liotti, Woldorff, Pecz, & Mayberg, 2000; Miltner, Braun, & Coles, 1997). This localization suggests that the ERN may represent the neurophysiological activity implicated in the fMRI studies of cerebral blood flow cited above. Although a similar localization has been obtained for the negativities elicited on trials with correct responses (Gehring & Willoughby, 2002), one recent study found evidence of different medial frontal sources for the ERNs elicited on correct and error trials (Ullsperger & Von Cramon, 2001). Because the relation between the negativities elicited on correct and error trials is not settled, we use Gehring and Willoughby’s (2002) term, medial frontal negativity (MFN), to refer to this activity when it is elicited on correct trials.

We also reasoned that deceptive responses might be differentiated on the basis of the source of the conflicting response information that must be inhibited. That is, one can be deceptive either about perceptual experiences as they occur or about things that one did or said at some time in the past. For example, when one responds falsely “the light is green” when it is actually red, the conflicting response information arises from external stimuli. In contrast, when one falsely states “I didn’t do that” about a past action, the source of conflicting response information arises from the internal representation of the person’s memory of the event. In this way, deceptions can be categorized as being perceptually based or memory based, respectively.

In the studies reviewed above, external events were used to deliver all the conflicting response information. Thus, although the memory-based response conflicts characteristic of deceptions about one’s past experiences may be similar to perceptually-based conflicts, the lack of any direct experimental comparisons leaves a number of unanswered questions. First, the extent to which the processes used to monitor and resolve perceptually-based response conflicts are the same as those used to monitor and resolve memory-based response conflicts is not known. Second, a major difference between all previous studies of response conflict and what occurs during deceptive responding is that of intentionality. That is, the idea that the ACC plays a role in monitoring performance to prevent erroneous responses is based on data from tasks in which participants made errors inadvertently. Although action monitoring is thought to play a role on all trials (Carter et al., 1998; Luu et al., 2000), it is not known if the same neural mechanisms would be invoked during deception since participants intentionally make errors as part of their goal to deceive. Third, the monitoring processes linked to the MFN and blood flow in the ACC were limited to those occurring within a trial (i.e., in the interval between the stimulus and the response to that stimulus), which could be described as being “tactical” in nature. Hence, we also hypothesized that persons would invoke additional control processes, referred to as “strategic” monitoring processes, to ensure that their responses both meet their overall goals and are consistently deceptive over extended time intervals. Hence, the extent to which these tactical and strategic monitoring processes are similar and share the same neural mechanisms needs to be determined.

In the study reported here, we measured both behavioral performance and brain electrical activity while participants responded truthfully and deceptively in a series of conditions that were designed to provide four specific comparisons to isolate different response-related control processes that would be involved in making deceptive responses. First,
about the nature of the experiment and signed informed consent. This was done by comparing performance and ERP activity in a perceptual task ("left" and "right" discrimination) with that in a memory task (old-new recognition) when compatible (truthful) and incompatible (deceptive) responses were made in separate conditions. To ensure that the decisions in the memory tasks were based on information contained in the participant’s episodic memory, only the old items from the Consistent Truthful and Consistent Deceptive conditions were used in this comparison. Due to the large differences in difficulty between the perceptual and memory tasks, in addition to differences in memory status, a second within-task comparison was made using only data from the memory conditions. This comparison contrasted the results of the Consistent Truthful and Consistent Deceptive conditions to isolate the relative effects of response compatibility responses (truthful versus deceptive) and memory status (old versus new). Together, the outcomes of these two comparisons also provide information on whether the processing of conflicting response information varies as a function of task difficulty. The third comparison was designed to determine if there were differences in performance and brain activity as a function of the type of monitoring processes (tactical versus strategic) that were used in task performance (Consistent Deceptive versus Random Deceptive). Because participants made the same deceptive responses to the same stimuli in both these conditions, differences across conditions would not be attributable to such extraneous factors as stimulus differences, the presence of conflicting response information or the need to make a deceptive response. The final comparison, based on the fact that it was necessary to perform the strategic monitoring processes continuously for all the events in the series, contrasted the results from the two types of trials within the Random Deceptive condition (Random Truthful responses versus Random Deceptive responses). The continuous nature of the strategic monitoring task led us to expect greater similarity between the truthful and deceptive responses within the Random Deceptive condition than in the conditions requiring only tactical monitoring processes.

2. Methods

2.1. Participants

Twenty-five graduate and undergraduate students (15 females) at Queens College were paid US$ 10.00 per hour for their participation. All participants were right-handed native English speakers with normal or corrected-to-normal vision. The data from four participants were excluded (see below) and the mean age of the remaining participants was 21.6 years (S.D. = 3.1). Participants were thoroughly briefed about the nature of the experiment and signed informed consent was obtained from each in accord with Queens College Institutional Review Board procedures.

2.2. Stimuli

One week prior to the experimental session, participants were given a list of 60 unrelated words to memorize ("old" words). They were told to study and learn the list before the experimental session when they would be given a series of recognition tests. No criterion was specified. After electrode placement, participants were seated in a dimly-lit room. In each memory condition, 58 of the 60 old words were randomly presented along with 58 new words on a CRT for 300 ms in all uppercase letters, using white letters on a black background (2750 ms average trial duration). Different lists of new words were used for each test, picked from a pool of 15 lists that were constructed by randomly selecting words from a master list, with all lists balanced for word frequency (Carroll, Davis, & Richman, 1971). The list of old words was also drawn from this set of 15 lists. The particular list of new words used in each condition was selected randomly (without replacement) for each participant. In addition to the 58 old and 58 new words, each series contained 29 “catch” trials on which the words "OLD" and “NEW” were presented randomly and equally often (see below). Thus, overall stimulus probabilities were 40% old words, 40% new words, 10% catch "OLD” and 10% catch “NEW.”

2.3. Procedure

Participants performed an old/new recognition test under three instructional conditions: Consistent Truthful, Consistent Deceptive and Random Deceptive. Over the session, participants performed these memory conditions twice. For the first repetition, the Consistent Truthful condition was performed first in order to determine how well participants knew the list at the beginning of the session. For the two deception conditions, half the participants performed the Consistent Deceptive condition before the Random Deceptive condition and half received the opposite order. For the second repetition, the order of all three memory conditions was randomized across participants. In the Consistent Truthful condition, participants pressed one button on a response box when they saw an old word or the word “OLD” and the other button when they saw a new word or the word “NEW.” In the Consistent Deceptive condition, although participants were instructed initially to make the same responses as in the Consistent Truthful condition, they were then told “to lie or try to hide what you know by pressing opposite of my instructions” (e.g., press the button designated “old” for new words). In the Random Deceptive condition, participants were instructed “to lie or hide what you know by pressing randomly” in a manner that met two goals: (1) to respond as randomly as possible while making approximately equal numbers of truthful and deceptive responses for both old and new words and (2) to
monitor both the number and pattern of their responses at each point in the series to determine which future responses were required to meet these goals. In the memory conditions, the pairing of responding hand with the response buttons was counterbalanced across participants.

Because participants were instructed to press opposite of the truth for every stimulus in the Consistent Deceptive condition, there would be nothing to prevent them from simply reversing the stimulus-response assignments in order to eliminate the conflicting response information. To prevent the use of this strategy, catch trials were presented randomly on 20% of the trials in all memory conditions. Participants were told that these trials were included “to keep you honest” and they were instructed “that it is important that you try hard to always press correctly [on the catch trials] so it will not be obvious that you are pressing the opposite buttons on the other trials.” The presence of catch trials meant that participants made 20, 60 and 100% truthful responses in the Consistent Deceptive, Random Deceptive and Consistent Truthful conditions, respectively.

There were two perceptual conditions in which the words “LEFT” and “RIGHT” appeared randomly and equiprobably. In the Perceptual Compatible condition, participants pressed the button on the side indicated by the stimulus (i.e., the response box contained two side-by-side buttons, one each to the left and right of the centerline). In the Perceptual Incompatible condition, participants pressed the button on the side opposite that indicated by the stimulus (e.g., right button for “LEFT”). Stimulus and trial timings in the perceptual conditions were identical to those used in the recognition conditions. There were 40 trials for each stimulus in the perceptual conditions. No stimulus-related differences in the behavioral or ERP measures were expected in the perceptual conditions and none were found so the data for “LEFT” and “RIGHT” trials were combined. The perceptual conditions were each performed once in the session with half the participants performing them before any of the memory conditions and half after completing the memory conditions. Participants were instructed to respond as quickly as possible in all conditions.

The duration of the perceptual and memory conditions was 3.7 and 6.6 min, respectively, and participants determined the duration of their breaks between series. Overall, the session lasted from 3 to 3.5 h, including electrode placement and removal and cleanup.

Only the memory data from the second repetition are presented here because large differences in ERP activity have been found to occur due to practice effects in a series of repeated recognition tests (see Johnson, Pfefferbaum, & Kopell, 1985; Johnson, Kreiter, Russo, & Zhu, 1998). Because the Consistent Truthful series was always performed initially, this lack of counterbalancing could potentially confound all truthful-deceptive comparisons by exaggerating possible differences across truthful and deceptive conditions. Therefore, the present analyses are based only the data from the second repetition when the conditions were completely counterbalanced and practice effects on the recognition task are known to be minimal. Analyses of the repetition effects for each condition are beyond the scope of this paper and are thus presented elsewhere (Johnson, Barnhardt, & Zhu, submitted for publication).

2.4. ERP recordings and quantification

ERP activity was recorded from 32 scalp sites, all referred to a left pre-auricular electrode, using tin electrodes embedded in an elasticized cap. The sites (FP1, FP2, F7, F3, Fz, F4, F8, FC5, FC1, FC2, FC6, T7, T3, Cz, C4, T8, CP5, CP1, CP2, CP6, P7, P3, Pz, P4, P8, O1, O2, C1, C2, right pre-auricular, E1, E2) were located in accord with the American Electroencephalographic Society guidelines (1991). To reduce the presence of possible electromyographic artifacts, the C1 and C2 electrodes were placed 1.2 cm above their standard International 10–20 System locations. Participants were grounded with a forehead electrode.

The EEG was amplified 10,000 times with a bandpass of 0.01–35 Hz (−3 dB/octave) and sampled at 100 Hz. Eye movements (EOG) were recorded from above (FP1) and 2 cm below the outer canthus of the left eye (E1) and trials contaminated with EOG artifacts (signals greater than 50 μV during any of the 115 sampling points) were excluded from the averages. During averaging, all scalp-recorded activity was digitally re-referenced to an average of the left and right pre-auricular sites. Response-locked ERPs were calculated for a 1150 ms epoch, extending from 650 ms before the response (including a 150 ms baseline) until 500 ms after the response. MFN activity was quantified by calculating the waveform area between 0 and 100 ms after the response, after subtracting the activity in the 150-ms baseline.

Behavioral data were tested in a series of two-way ANOVAs using the factors Condition and Stimulus (old, new). For the MFN area data, the same ANOVA design was used with the addition of an Electrode factor, using data from the eight central–frontal sites (F3, Fz, F4, FC1, FC2, C3, Cz, C4). Because using data from multiple electrode sites may lead to a violation of the sphericity assumption, all ANOVA results were corrected using the Greenhouse–Geisser procedure.

2.5. Analyses of MFN scalp topography

The presence of possible topographic differences between conditions, signifying that different patterns of neural generator activity were present, is revealed by significant interactions between the experimental and electrode factors in an ANOVA (McCarthy & Wood, 1985). However, in some cases, significant interactions can result from amplitude differences alone, with no change in scalp distribution. It is necessary, therefore, to perform a topographic profile comparison on MFN amplitudes that have been normalized to remove any confounding amplitude differences due to factors other than topography (Johnson, 1993; Ruchkin,
behavioral data were compared in a series of 2 × 2 randomized between-subjects ANOVAs using the factors (e.g., electrode and task) in a Greenhouse-Geisser epsilon-corrected ANOVA.

3. Results

3.1. Excluded participants

The monitoring demands made the Random Deceptive condition sufficiently difficult that some participants had trouble making roughly equal numbers of responses in each category. Because the validity of comparisons involving the Random Deceptive condition are dependent on the extent to which the monitoring task was performed successfully, the number of trials in each of the four response categories was assessed for each participant. Four participants produced truthful deceptive ratios varying around 3:1 or 1:3, rather than the ideal of 1:1, and thus were dropped from the analyses. Even without this criterion, the extent of their category imbalances would have meant that there were too few trials to generate ERP averages for the under-represented categories. The data presented here are from the remaining 21 participants.

3.2. Comparison of response conflict elicited in perceptual and memory tasks

To determine the extent to which the tactical monitoring processes used in perceptually- and memory-based response conflicts are similar, the results from the Perceptual Compatible and Incompatible conditions were compared with those for the old words in the Consistent Truthful and Consistent Deceptive conditions. These comparisons used the old words so there was a memory difference across conditions. The behavioral data were compared in a series of 2 × 2 ANOVAs using the factors Response (Truthful, Deceptive) and Task (Perceptual, Memory). The analyses of the ERP results used the same ANOVA design except for the addition of an Electrode factor. Note that, in contrast to the clear use of truthful/deceptive instructions in the memory task, the responses in the perceptual tasks are more accurately characterized as being compatible and incompatible with the stimuli. However, to avoid circumlocution, the terms truthful and deceptive will be used for both tasks.

As can be seen in Table 1 and Fig. 1A, deceptive responses were about 2.5% less accurate overall compared to truthful responses \( F(1,20) = 10.3, P < 0.005 \) and deceptive RTs were an average of 58 ms slower than truthful RTs \( F(1,20) = 32.2, P < 0.00002 \). The memory task was more difficult than the perceptual task, as evidenced by the participants’ lower accuracy [92.8% versus 96.8%, respectively: \( F(1,20) = 5.7, P < 0.05 \)] and 188 ms slower RTs \( F(1,20) = 419.8, P < 0.00001 \). Nevertheless, despite the differences in task difficulty, there were no differences across tasks in the extent to which a deceptive response slowed RT (Response × Task: \( P = 0.12 \)).

RT variability, quantified as the standard deviation of RT, also varied across conditions (Fig. 1B). Overall, RT distributions for deceptive responses were broader and less peaked compared to those for truthful responses for both perceived and remembered stimuli. An ANOVA on the S.D.s revealed that deceptive responses were significantly more variable than truthful responses [100 ms versus 84 ms; \( F(1,20) = 33.5, P < 0.00002 \] and RTs were more variable in the memory task [102 ms versus 82 ms: \( F(1,20) = 37.6, P < 0.00002 \]. As was the case for RT, the Response × Task interaction was not significant (\( F < 1 \)), indicating there were no differences across tasks in the extent to which RT variability increased for deceptive responses. According to the logic of the Additive Factors Method (Sternberg, 1969), variables that affect mental processes that occur independently and/or in separate processing stages produce significant main effects in an ANOVA, but no significant interaction. Using this framework, our results reveal that the task and response compatibility variables both had independent and additive effects on response speed and variability.

The ERPs elicited in these four conditions are presented in Fig. 2 where the MFN is evident as a negative-going component that peaked around 70 ms after the response. These

<table>
<thead>
<tr>
<th>Perceptual task</th>
<th>Memory task*</th>
<th>Compatible</th>
<th>Incompatible</th>
<th>Consistent Truthful</th>
<th>Consistent Deceptive</th>
<th>Random Truthful</th>
<th>Random Deceptive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Left/right</td>
<td></td>
<td>98.1 (2.6)</td>
<td>95.4 (3.9)</td>
<td>94.0 (8.6)</td>
<td>91.5 (8.3)</td>
<td>52.6 (8.0)</td>
<td>47.8 (8.2)</td>
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<tr>
<td></td>
<td></td>
<td>94.9 (13.8)</td>
<td>91.6 (11.1)</td>
<td>50.6 (5.2)</td>
<td>49.0 (5.4)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*For the Perceptual Incompatible, Consistent Deceptive and Random Deceptive response categories, percent correct refers to the percentages of responses with the opposite hand whereas in the Consistent Truthful and Random Deceptive conditions, this represents the percentage of deceptive responses indicating non-recognition of OLD words and recognition of NEW words. For the memory conditions, these percentages were determined based on the known status (OLD or NEW) of the stimuli.

*For the Random Deceptive condition, these headings refer to the two possible response outcomes within that condition.
waveforms reveal a complex pattern of MFN activity at the four central–frontal sites where this ERP component was maximal. For example, visual inspection of the waveforms suggests that although MFN amplitude varied primarily as a function of response compatibility at the central site (Cz), both response compatibility and task affected MFN amplitude at the central–frontal (i.e., FC1, FC2) and frontal (Fz) sites. The ANOVA on MFN amplitude revealed that significantly larger MFNs were elicited both for deceptive responses compared to truthful responses $[F(1, 20) = 17.3, P < 0.0005]$ and by remembered compared to perceived stimuli $[F(1, 20) = 5.4, P < 0.05]$. Consistent with the behavioral results, the absence of a significant Response $\times$ Task interaction ($F < 1$) indicates that these two variables had independent effects on MFN amplitude.

This ANOVA also confirmed that amplitude varied significantly over central–frontal scalp [Electrode: $F(7, 140) = 68.9, \epsilon = 0.300, P < 0.00001$]. Moreover, the different patterns of MFN amplitude variations over the scalp resulted in significant Response $\times$ Electrode $[F(7, 140) = 2.1, \epsilon = 0.300, P < 0.05]$ and Task $\times$ Electrode $[F(7, 140) = 2.5, \epsilon = 0.300, P < 0.02]$ interactions. Because such results raise the possibility that there are different patterns of neural generator activity for each type of response and task, the data were normalized to remove any condition effects. ANOVAs on the normalized amplitudes revealed significant Response $\times$ Electrode interactions for both the Perceptual $[F(7, 140) = 5.9, \epsilon = 0.345, P < 0.01]$ and Memory tasks $[F(7, 140) = 4.8, \epsilon = 0.277, P < 0.05]$, confirming that the MFNs elicited by deceptive responses in both conditions were due to a different pattern of brain activity than responsible for the truthful MFNs. Similarly, after normalization, significant Task $\times$ Electrode interactions were found for both truthful $[F(7, 140) = 5.8, \epsilon = 0.326, P < 0.01]$ and deceptive responses $[F(7, 140) = 4.7, \epsilon = 0.342, P < 0.02]$, confirming that the MFN elicited in the perceptual task was due to a different pattern of brain activity than that elicited in the memory task for both truthful and deceptive responses. Thus, the data indicate that the MFNs recorded here are due to a composite of two approximately simultaneous patterns of neural generator activity, one related to the processing of task-related information and another related to the processing of response-related information.
Fig. 2. The ERP activity elicited at the four central–frontal sites by the Perceptual Compatible and Perceptual Incompatible stimuli and by old words in the Consistent Truthful and Consistent Deceptive conditions. The MFN component is the large negativity between 0 and 100 ms after the response that peaks around 60 ms. Note that the waveforms for the Perceptual Incompatible condition are difficult to discern around the time of the response at the three anterior sites because they are nearly the same as those elicited during the Consistent Truthful condition. In this and subsequent figures, the ERP epoch spans the interval from 650 ms prior to the button press until 500 ms afterwards (100 ms/tick). The vertical line in the center of the x-axis marks when the response button was pressed (i.e., time 0). Negative voltages are plotted as upward deflections.

The ERPs in Fig. 2 also reveal that there was no systematic relation between MFN amplitude and task difficulty (as indexed by RT differences), despite the fact that RT varied over a considerable range (i.e., from 396 to 646 ms). Further, the relations between the changes in RT and MFN amplitude were different for the two experimental variables. Thus, whereas manipulations of response compatibility had a relatively small effect on task difficulty (RT was 68 and 48 ms longer for the perceptual and memory tasks, respectively), there were large changes in MFN amplitude. Conversely, manipulations of task demand had large direct effects on RT but no effect, or an inverse effect, on MFN amplitude. That is, despite the fact that the Consistent Truthful condition was more difficult than the Perceptual Incompatible condition (i.e., RT was 138 ms slower), Consistent Truthful MFNs were actually equal to or smaller than those elicited in the Perceptual Incompatible condition (at Cz). Taken together, the data indicate that while factors affecting response processing had large effects on MFN amplitude, factors affecting task difficulty did not.
3.3. Response conflict as a function of memory status

New words are typically categorized more slowly than old words, indicating that memory status influences task difficulty. To determine if the results of the perceptual-memory comparisons also obtained when difficulty was varied within a task, the old and new word data from the Consistent Truthful and Consistent Deceptive conditions were tested in a series of ANOVAs using the factors Response (Truthful, Deceptive) and Stimulus (Old, New).

As shown in Table 1, overall accuracy in the Consistent Truthful and Consistent Deceptive conditions was not different \(F < 1\). In contrast, deceptive RTs were slower than truthful RTs by an average of 52 ms \(F(1, 20) = 28.3, P < 0.0005\) and, in accord with past studies, RTs for new words were an average of 44 ms slower than RTs for old words \(F(1, 20) = 21.0, P < 0.0002\) (Fig. 1A). Using the Additive Factors logic, the lack of a Response × Stimulus interaction \(F < 1\) indicates that the effect of response conflict on RT was independent of whether participants were deceptive by falsely denying knowing words that they did know or falsely claiming to know words that they did not know. Similarly, as shown in Fig. 1B, RT variability was also significantly greater for deceptive compared to truthful responses \(F(132 \text{ ms} \times 102 \text{ ms}, \text{ respectively}; F(1, 20) = 7.9, P < 0.0005\) and for new words compared to old words \(F(110 \text{ ms} \times \text{versus} 123 \text{ ms}, \text{ respectively}; F(1, 20) = 11.0, P < 0.005\). Consistent with the RT results, the Response × Stimulus interaction was not significant \(F(1, 20) = 1.5, P = 0.24\), indicating that response conflict also affected RT variability independently of the memory status of the words.

It is evident from the ERPs elicited in these conditions (Fig. 3) that new words elicited larger MFNs than old words \(F(1, 20) = 12.1, P < 0.005\) and that deceptive responses elicited larger MFNs than truthful responses \(F(1, 20) = 9.1, P < 0.01\). However, the magnitude of the response incompatibility effects was not different as a function of the memory status of the words (Response × Stimulus: \(F < 1\)). The variations in MFN amplitude over the scalp were also significant [Electrode: \(F(7, 140) = 60.4, \epsilon = 0.287, P < 0.0001\)]. As can be seen in Fig. 3, memory status appeared to affect MFN amplitude maximally at central sites (Cz), less at central-frontal sites (FC1, FC2) and not at all at frontal sites (Fz). In contrast, these ERPs also suggest that, although deceptive responses elicited larger MFNs at central and frontal sites, the amplitude differences at frontal sites appeared to be due exclusively to the effects of response conflict. Topographic profile comparisons on normalized amplitudes revealed significant Response × Electrode \(F(7, 140) = 6.1, \epsilon = 0.287, P < 0.005\) and Stimulus × Electrode \(F(7, 140) = 4.0, \epsilon = 0.287, P < 0.05\) interactions, indicating that different patterns of neural generator activity were responsible for the response and stimulus processing contributions to overall MFN amplitude, respectively. To further assess the effects of the Response and Stimulus variables on MFN scalp distribution, we performed ANOVAs on MFN amplitudes from the Cz and Fz sites alone. These three-way ANOVAs included a Location (Anterior (Fz), Central (Cz)) factor, in addition to the Stimulus and Response factors described above. These tests revealed that, even when restricted to these two sites, the Response × Location \(F(1, 20) = 8.2, P < 0.01\) and Stimulus × Location \(F(1, 20) = 52.1, P < 0.00001\) interactions remained significant. These results therefore confirm the visual impressions from the ERPs in Fig. 3 of differential topographic patterns of MFN activity for the Response and Stimulus variables.

3.4. Comparison of effects of different executive processes: strategic versus tactical monitoring

The differential effects of strategic and tactical monitoring on behavioral and ERP activity were assessed by contrasting the results from the Consistent Deceptive condition with those for the Random Deceptive responses. Note that, because there were two response outcomes within the Random Deceptive condition, these outcomes will be referred to as Random Deceptive responses and Random Truthful responses. Thus, the old and new word data from these conditions were tested in a series of ANOVAs using the factors type of Monitoring (Tactical, Strategic) and Stimulus (Old, New). A second set of within-condition comparisons were also made in which the Random Deceptive responses were compared to the Random Truthful responses in a series of ANOVAs using the factors type of Response (Truthful, Deceptive) and Stimulus (Old, New).

As evident from Fig. 1A, making Random Deceptive responses was more difficult and caused RT to slow by an additional 96 ms over that in the Consistent Deceptive condition \(F(1, 20) = 9.1, P < 0.01\). However, RTs remained an average of 47 ms slower for new words than old words over conditions \(F(1, 20) = 15.2, P < 0.001\). Again, the degree of RT slowing was not different as a function of the memory status of the words [Monitoring × Stimulus: \(F < 1\)]. Fig. 1B shows that participants’ RTs were also significantly more variable when they strategically monitored the pattern of their Random Deceptive responses. The S.D. of the RT increased to an average of 186 ms for Random Deceptive responses compared to an average of 132 ms in the Consistent Deceptive condition \(F(1, 20) = 31.8, P < 0.0005\). The S.D. of the RT for new words (168 ms) was also significantly greater than the S.D. for old words (150 ms) \(F(1, 20) = 6.1, P < 0.05\). The amount of increased RT variability in the Random Deceptive condition was not different across stimuli [Monitoring × Stimulus: \(F < 1\)].

The waveforms in Fig. 4 reveal that the MFNs elicited by Random Deceptive responses were considerably larger than those elicited in the Consistent Deceptive condition \(F(1, 20) = 19.5, P < 0.0005\). The relatively small overall amplitude differences as a function of stimulus, however, meant that this effect only approached significance.
As in previous comparisons, the Monitoring × Stimulus interaction was not significant \((P = 0.15)\). The waveforms in Fig. 4 reveal that, although MFN amplitude varied as a function of memory status and type of monitoring at central (e.g., Cz) sites, only type of monitoring affected MFN amplitude at frontal (e.g., Fz) sites [Electrode: \(F(7, 140) = 44.8, \epsilon = 0.371, P < 0.00001\)]. To assess the effects of the experimental variables on MFN scalp distribution, we performed ANOVAs on the data from the Cz and Fz sites alone. These three-way ANOVAs included a Location (Anterior (Fz), Central (Cz)) factor, in addition to the Stimulus and Monitoring factors described above. These tests confirmed that, even when restricted to these two sites, type of monitoring [Monitoring × Location: \(F(1, 20) = 27.9, P < 0.00005\)] and memory status [Stimulus × Location: \(F(1, 20) = 11.0, P < 0.005\)] each had different effects on MFN amplitude at different scalp sites. Topographic profile comparisons confirmed that the MFNs elicited by Random Deceptive responses had a significantly different pattern of generator activity than the MFNs elicited in the Consistent Deceptive condition [\(F(7, 140) = 13.6, \epsilon = 0.379, P < 0.00005\)].

To assess possible within-task differences between making Random Truthful and Random Deceptive responses, the data from these two response outcomes were compared. As in the Consistent Truthful and Consistent Deceptive conditions, RT was significantly slower by an average of 26 ms for the Random Deceptive responses compared to the Random Truthful responses [\(F(1, 20) = 13.6, P < 0.002\)] (Fig. 1). Similarly, RTs were an average of 29 ms faster for
old words than for new words \(F(1, 20) = 7.5, P < 0.02\) and the Response × Stimulus interaction was not significant \((P = 0.17)\). As can be seen in Fig 1B, RTs were also somewhat more variable for Random Deceptive responses compared to Random Truthful responses (i.e., by 15 ms), but this difference only approached significance \(F(1, 20) = 3.2, P = 0.09\).

The ERPs elicited by the Random Deceptive and Random Truthful responses are superimposed in Fig. 5. These waveforms reveal that, while MFN amplitude varied as a function of site \(F(7, 140) = 28.2, \epsilon = 0.380, P < 0.00001\), uniformly large MFNs were elicited at all sites, regardless of Stimulus \((F < 1)\) or Response compatibility \((F < 1)\) factors. Further, there were no apparent topographic differences for the MFNs elicited for Random Deceptive and Random Truthful responses \(\text{Response} \times \text{Electrode}: F < 1\).

### 3.5. MFN topography

The topographic characteristics of the scalp-recorded voltages for the temporal interval containing the peak of the MFN were displayed visually by calculating contour maps using the spherical spline method (Perrin, Pernier, Bertrand, & Echallier, 1989) and data from all 32 electrode sites (Fig. 6). These maps reveal that MFN activity appeared as a diffuse negativity over frontal scalp in the Perceptual (left column) and Consistent Truthful and Consistent Deceptive conditions (second column). At the same time, there was a large LPC over posterior scalp in all conditions. The significant topographic differences in MFN activity described above between deceptive (bottom row) and truthful responses (top row) are evident as the exaggerated “dip” in the contour lines over central scalp in the
Fig. 5. The ERPs elicited by the Random Truthful responses and Random Deceptive responses for old and new words at the four central–frontal sites.

maps of deceptive responses (arrow). Moreover, the finding of significant topographic differences between the MFNs elicited in the Consistent Deceptive and Random Deceptive conditions (see above) is clearly evident in the maps for these two conditions. That is, there was a much stronger central–frontal negativity, along with a much weaker parietal LPC, in the Random Deceptive condition compared to those elicited in the Consistent Deceptive condition.

To determine if these MFN topographic differences were due specifically to the experimental effects, ERP difference waveforms were calculated (Fig. 7). That is, the effect of processing conflicting response information in both the perceptual and memory conditions was isolated by subtracting the ERPs for truthful responses from the ERPs for deceptive responses (i.e., Perceptual Incompatible–Perceptual Compatible and Consistent Deceptive–Consistent Truthful, separately for the old and new words). To isolate the effects of strategic monitoring, the ERPs for the Consistent Deceptive condition were subtracted from those for the Random Deceptive responses and Random Truthful responses (separately for the old and new words). It is evident from the waveforms in Fig. 7 that there was little if any difference in ERP activity during the 0–100 ms MFN interval between the perceptual and memory conditions at any central–frontal scalp site. This is consistent with the analyses above indicating that the effects of response conflict on all behavioral and ERP measures were the same regardless of the source of the conflicting response information. In contrast, the difference waveforms representing the MFN activity related to strategic monitoring processes had much larger amplitudes at the three central and central–frontal sites compared to the response conflict difference waveforms. To test the differences from the memory conditions, an ANOVA was done on amplitudes in the difference ERPs in the MFN interval (40–100 ms) using the factors Condition (Consistent Deceptive–Consistent Truthful versus Random...
Fig. 6. Voltage maps (110° projections) showing brain activity in the interval from 40 to 100 ms after the participant’s response (front of the head at top). These maps show the distribution of negative (shaded) and positive (unshaded) voltages, calculated on the basis of the across-participant averages. The top and bottom rows show the brain activity when participants made truthful and deceptive responses, respectively. The first column shows the data from the Perceptual Compatible and Perceptual Incompatible conditions. The second column shows the data for the old words from the Consistent Truthful and Consistent Deceptive conditions. The third and fourth columns show the data from the Random Deceptive condition, separately for the old (third column) and new words (fourth column) and separately for the truthful (top row) and deceptive (bottom row) responses.

Deceptive responses—Consistent Deceptive), Stimulus (old, new) and Electrode. This analysis confirmed the presence of an effect of Electrode \( F(7, 140) = 22.5, \eta^2 = 0.333, P < 0.00001 \) and a significant Condition × Electrode interaction \( F(7, 140) = 6.4, \eta^2 = 0.333, P < 0.005 \). As would be expected from the waveforms in Figs. 3 and 4, neither the effect of Stimulus (\( P = 0.156 \)) nor the Stimulus × Electrode interaction was significant (\( P = 0.55 \)). Thus, these results support the conclusion that the MFN distribution differences between the tactical and strategic monitoring conditions were due to the experimental manipulations.

The difference waveforms also reveal another difference between the brain activity in the strategic and tactical monitoring conditions. That is, there was a negativity at all four central–frontal sites that began about 150 ms prior to the response and continued until the response was made. In contrast, there was little of this activity for simple response conflicts in the perceptual and memory conditions, with the same small amount of negativity present in both these conditions. To determine if there were significant differences in this activity across conditions, another ANOVA was done on the amplitude differences in the \(-150 to 0\) ms interval using the same design as for the MFN differences. As would be expected from the larger ERP amplitudes for Random Deceptive responses, both the effect of Condition \( F(1, 20) = 5.1, P < 0.05 \) and the Condition × Electrode interaction \( F(7, 140) = 8.9, \eta^2 = 0.331, P < 0.0001 \) were significant. Again, there was no effect of Stimulus (\( P = 0.251 \)) nor was the Stimulus × Electrode interaction significant (\( P = 0.42 \)), although there was an overall effect of Electrode \( F(7, 140) = 12.8, \eta^2 = 0.331, P < 0.00005 \).

These results suggest that there is additional brain activity elicited prior to the response when strategic monitoring of responses is necessary.

3.6. Relation of MFN amplitude to task difficulty

Overall, both RT and MFN amplitude increased progressively from the Consistent Truthful to the Consistent Deceptive to the Random Deceptive condition. Although there was no relation between MFN amplitude and task difficulty in the perceptual-memory comparisons (see above), the findings from the memory deception conditions raise the possibility that these changes in MFN amplitude were due to differences in task difficulty rather than to the requirement to make or monitor deceptive responses. To evaluate the relation between task difficulty and MFN amplitude, a median-split analysis was conducted in which each participant’s trials were sorted separately for each condition according to whether the RT was above or below their median RT for that condition.

First, we compared the RTs for the difficult (i.e., slow RTs) Consistent Deceptive trials with those for the easy (i.e., fast RTs) Random Deceptive responses. As can be seen in Table 2, RTs for the easy Random Deceptive responses were an average of 139 ms faster than those for the difficult
Fig. 7. The ERP difference waveforms elicited at the four central–frontal sites revealing the effects of response conflict and strategic monitoring across conditions. The Perceptual-Response Conflict waveforms were obtained by subtracting the ERPs for the Perceptual Compatible condition from those for the Perceptual Incompatible condition (thin solid line). The Memory-Response Conflict waveforms were obtained by subtracting the ERPs for the Consistent Truthful condition from those for the Consistent Deceptive condition (dotted line). The Strategic Monitoring waveforms were obtained by subtracting the ERPs for the Consistent Deceptive condition from those for the Random Deceptive responses (thick solid line). For clarity, only the difference ERPs for old words in the memory conditions are shown.

Table 2
Mean RT (ms) and (S.D.) as a function of condition for median-split RT analyses

<table>
<thead>
<tr>
<th>Condition</th>
<th>RT (S.D.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consistent Deceptive—above median RT</td>
<td></td>
</tr>
<tr>
<td>Old words</td>
<td>734 (112)</td>
</tr>
<tr>
<td>New words</td>
<td>794 (128)</td>
</tr>
<tr>
<td>Random Deceptive responses—below median RT</td>
<td></td>
</tr>
<tr>
<td>Old words</td>
<td>609 (62)</td>
</tr>
<tr>
<td>New words</td>
<td>638 (94)</td>
</tr>
<tr>
<td>Random Deceptive responses—above median RT</td>
<td></td>
</tr>
<tr>
<td>Old words</td>
<td>868 (141)</td>
</tr>
<tr>
<td>New words</td>
<td>936 (147)</td>
</tr>
</tbody>
</table>

Consistent Deceptive trials ($F(1, 20) = 28.3, P < 0.00005$). Nevertheless, old words continued to elicit faster RTs than new words ($F(1, 20) = 13.6, P < 0.005$). Similarly, RTs were now significantly less variable for the easy Random Deceptive responses, by an average of 33 ms, compared to the difficult Consistent Deceptive trials ($F(1, 20) = 21.8, P < 0.00005$). Thus, behaviorally, the data indicate that the fast Random Deceptive responses were easier to perform than the slow Consistent Deceptive trials. The median-split ERP averages (Fig. 8) clearly show that, despite reversing the difficulty relation between these two conditions, larger MFNs were still elicited on the easy Random Deceptive responses (compare to Fig. 4) ($F(1, 20) = 6.4, P < 0.02$). Note also that the mean RTs for the easy Random Deceptive
old and new responses (613 and 638 ms, respectively) were nearly the same as the mean RTs based on all Consistent Truthful trials (598 and 639 ms for old and new words, respectively). Therefore, even when RTs were equated across conditions in this way, the MFNs elicited on the easy Random Deceptive responses were still much larger than those elicited in the Consistent Truthful condition (i.e., compare Fig. 8 with Fig. 3).

The relation between MFN amplitude and task difficulty was also evaluated by comparing the fast and slow trials for both the Random Deceptive and Random Truthful responses. Behaviorally, there was an average 279 ms difference between the mean RTs for fast and slow trials \( F(1, 20) = 169.2, P < 0.00001 \) and the S.D. of RT was 56 ms greater for slow trials \( F(1, 20) = 34.9, P < 0.00002 \). The ERPs for the fast and slow Random Deceptive responses, superimposed in Fig. 9, reveal little variation in MFN amplitude either as a function of RT \( (F < 1) \) or as a function of memory status. Note that this 279 ms average RT difference between the easy and difficult trials is greater than the entire RT range between the fastest Consistent Truthful RT and the slowest Random Deceptive RT (Fig. 1).

Taken together, the data from these three comparisons provide different and independent types of evidence against the hypothesis that the across condition differences in MFN amplitude were due to variations in task difficulty as indexed by RT.

4. Discussion

On the basis of this study, we have elucidated some of the cognitive processes and neural mechanisms underlying deceptive responses about both perceived and remembered...
Fig. 9. A comparison of the ERPs elicited by old and new words with RTs above (OldA, NewA) and below (OldB, NewB) the median RT for the Random Deceptive responses.

Behaviorally, we found that Consistently Deceptive responses were less accurate, slower and more variable than truthful responses, all consistent with the presence of conflicting response information. The ERP data revealed that, compared to the MFNs elicited by Consistent Truthful responses, the MFNs for Consistent Deceptive responses were not only significantly larger but this enhancement was generated by a different pattern of brain activity than generated the MFNs for truthful responses. Because the essentially identical results were found in comparisons of the results from the Perceptual Compatible and Perceptual Incompatible conditions, the data further suggest that the executive control processes used to make deceptive responses are general-purpose in nature. When participants also had to monitor strategically the overall pattern of their responses, their RTs became much slower and more variable and their MFN amplitudes increased considerably, even when compared to the Consistent Deceptive condition. This additional MFN activity elicited during strategic monitoring was found to be generated by a third pattern of medial frontal brain activity. Importantly, we also showed that the increased MFN activity in the two deception conditions was not due to variations in task difficulty across conditions. Taken together, the data suggest that two anatomically dissociable executive processes, that normally help resolve response conflicts and regulate actions, are also used when persons make and monitor their deceptive responses.

The experimental conditions and comparisons employed here to reveal deception-related processing are consistent with the criteria set forth by Furedy et al. (1988) as necessary to identify the psychological processes that are specifically related to deception. These authors maintained that, in order to study deception properly, it is necessary to use conditions that vary only with respect to deception. An
important aspect of their approach was the use of procedures to control such extraneous factors as item significance and frequency of occurrence and ease of retrieval. For example, they suggested that possible differences in retrieval difficulty could be reduced by presenting the task to the participants as a deception test, rather than a memory test. Our use of a standard recognition paradigm with equally probable and randomly chosen old and new words eliminated differences in both frequencies of occurrence and the significance of the words across truthful and deceptive conditions. We also explicitly represented the different conditions as being either truthful or deceptive.

While Furedy et al. (1988) minimized memory retrieval demands through the use of autobiographical information, we minimized retrieval demands by using a well-learned word list. In addition, the present comparisons were based on the completely counterbalanced second repetition of the memory conditions when performance was at very high levels. Although not stating it directly, Furedy et al.’s (1988) differentiation of deception method is essentially equivalent to the additive factors approach used here to isolate the deception-related processes. Thus, the lack of any significant Stimulus × Response or Task × Response interactions for any of our behavioral or MFN measures, both across tasks (perceptual versus memory) and within tasks (Consistent Truthful versus Consistent Deceptive), provides empirical support for the idea that the processes used to make deceptive responses about perceived and remembered stimuli were independent of those related to other stimulus and task manipulations. Based on this pattern of results, we conclude that deception-related processing was successfully isolated and Furedy et al.’s (1988) criteria for studying deception were met.

4.1. Role of executive processes in deception

In our conceptualization, a central component of deception is the necessity of making a response that conflicts with the truth. As a consequence, we hypothesized that the executive control processes used to resolve conflicting response tendencies, including those necessary to inhibit the pre-potent truthful response, would play an important role in every deceptive response. In accord with previous studies of response conflict, we found that performance accuracy decreased slightly and that RT slowed and became more variable when perceived stimuli delivered conflicting response information (Barch et al., 2000; Carter et al., 1998; Casey et al., 2000; Gehring & Willoughby, 2002; Scheffers & Coles, 2000; Van Veen et al., 2001). Importantly, we extended these results by showing that MFN amplitudes increased concomitantly with these behavioral changes even when responses were correctly incorrect (i.e., deceptive). In addition, we demonstrated that, when participants made deceptive responses about what they knew to be true regarding items in their personal memory, the resulting alterations in behavioral and MFN activity were indistinguishable from those associated with perceptually-based conflicts. Moreover, these results were found regardless of whether participants falsely indicated not knowing items that were in their memory or falsely indicated knowing items that they did not know. The fact that the MFN alterations, in both amplitude and scalp topography, were not different as a function of the source or the nature of the conflicting response information is consistent with the idea that a single brain mechanism is responsible for resolving conflicting response information that may arise in a variety of circumstances.

The idea that there is a general-purpose brain mechanism for resolving response was supported further by the overall pattern of results revealing that the executive processes used to make deceptive responses appeared to be independent of a variety of other cognitive processes. That is, the same behavioral changes and MFN amplitude increases were found regardless of variations in stimulus (left–right versus all different words) or task (perceptual versus memory) processing demands, and regardless of the memory status of the items (old versus new). Perhaps most surprisingly, variations in the probability of making incompatible responses across conditions (100% versus 80%, in the Perceptual Incompatible and Consistent Deceptive conditions, respectively) also had no effect on any behavioral or MFN measures. This lack of probability effects, at least over this range, raises the possibility that, although our deceptive responses were more probable than the 14–17% levels used in previous ERP studies of guilty knowledge (e.g., Allen & Iacono, 1997; Allen et al., 1992; Farwell & Donchin, 1991), this difference may have no effect on the results. Thus, our behavioral and electrophysiological data all point to the existence of a general-purpose processor for resolving response conflicts that apparently functions at least somewhat independently of the circumstances surrounding the presentation of the conflicting information (cf. Ullsperger & Von Cramon, 2001).

In contrast to the tactical monitoring processes required in the Consistent Deceptive condition, the Random Deceptive condition was intended to require the kind of strategic monitoring processes that would be used to relate the selection of current responses to past responses in order to meet one’s long-term goals. When the effects of Consistent Deceptive and Random Deceptive responses were compared directly, RTs were much slower and more variable for Random Deceptive responses, presumably due to the need to strategically monitor their responses. In addition, MFN amplitude increased considerably for both Random Truthful and Random Deceptive responses when participants had to select and monitor their responses over the 145 events in the series. In accord with the continuous nature of the strategic monitoring task, we found that the pattern of altered RTs and MFN activity was the same regardless of whether participants’ responses were truthful or deceptive. Furthermore, these differences in MFN amplitude across the Consistent Truthful, Consistent Deceptive and Random Deceptive conditions held even when task difficulties were
equated or reversed. Taken together, these comparisons strongly support the idea that the MFN amplitude changes found here were related to the use of tactical and strategic monitoring processes and not to differences in task difficulty.

We expected that the long-term monitoring of response patterns in the Random Deceptive condition would impose an additional load on working memory. However, we found no changes in ERP activity over lateral frontal scalp resembling those previously associated with maintaining or updating working memory (e.g., Ruchkin et al., 1997, 1999; Ruchkin, Johnson, Grafman, Canoune, & Ritter, 1997). One explanation is that the memory loads imposed by the Random Deceptive task were less than those in typical working memory paradigms that require the participant to hold more items and/or continuously replace the current memory set with a list of new items. In addition, there are other experimental differences across paradigms. In particular, the monitoring intervals required here were many times longer than the few seconds typically used when participants hold a set of items in working memory paradigms. Consistent with this idea, blood flow studies have found relatively little ACC activity across a variety of working memory paradigms (see Cabeza & Nyberg, 2000 for a review) and, when compared directly, blood flow increases were much greater during episodic retrieval than when participants had to hold four words in working memory (Cabeza, Dolcos, Graham, & Nyberg, 2002). Even if it is assumed that our participants continuously held four counts in working memory, this load is the same or less than having to encode and hold four new unrelated words on each trial in the Cabeza et al. (2002) working memory task. Finally, when the relation between executive processes and verbal working memory was studied, the results showed that, when response conflict was introduced, blood flow increased in dorsolateral prefrontal cortex but not in the ACC (Smith & Jonides, 1999). This is in clear contrast to the results of the response conflict studies reviewed above. Hence, while the increased MFN activity in the Random Deceptive condition, relative to the other conditions, may reflect some working memory component, we believe that the majority, if not all, of the amplitude increase is due to use of strategic monitoring processes.

Engaging the additional executive processes required to make deceptive responses can be seen as being equivalent to a secondary task that the deceptive person must perform in addition to the primary task of responding truthfully. Deceptive responses should, therefore, also be distinguishable from truthful responses by the fact that they require more controlled processing resources. Given that ERP studies have demonstrated that the amplitude of the parietal maximal LPC decreases in a graded manner as resources are shifted from a primary task to a secondary task (Iseral, Chesney, Wickens, & Donchin, 1980; Iseral, Wickens, Chesney, & Donchin, 1980; Kramer, Wickens, & Donchin, 1985), this ERP component has been used as an indicator of how processing resources are allocated. A comparison of the amplitude changes for both the LPC (Johnson, Barnhardt, & Zhu, 2003; Johnson et al., submitted for publication) and MFN components recorded here indicates that the MFN amplitude increases found in the perceptual and memory tasks were each associated with proportionately similar LPC amplitude decreases (see Fig. 6). In addition, in every case where we found MFN amplitude increases that were independent of, and additive to, the other stimulus and task variables, the same additive relations were found for LPC amplitude decreases. Together, the results from these concurrently recorded, but independent ERP components, suggest that deceptive responses require more processing resources than truthful responses due to the use of these additional executive processes during deceptive responding.

4.2. Role of the anterior cingulate cortex in deceptive responding

The topographic analysis of the MFN activity suggests that this is a complex ERP component with multiple patterns of generator activity that contribute to its overall amplitude. We found three different patterns of MFN generator activity, all with essentially the same timing, that each showed a differential responsiveness to manipulations of stimulus, task and response processing variables. These MFN findings are in accord both with those of studies indicating that this activity is generated in medial frontal cortex, in or near the ACC (Dehaene et al., 1994; Gehring & Willoughby, 2002; Gehring et al., 2001; Liotti et al., 2000; Milner et al., 1997) and with previous proposals that the ACC is a functionally heterogenous brain area (Botvinick et al., 1999; Peterson et al., 1999; Swick & Jovanovic, 2002; Turken & Swick, 1999). The MFN results described here also fit with the hypothesis that the ACC plays an important role both in controlling and monitoring a person’s actions when there is conflicting information about which response is correct (e.g., Botvinick et al., 1999; Carter et al., 1998; Lau et al., 2000). We showed that the brain activity associated with the response conflicts that occurred during the execution of deceptive responses was independent of the source of the conflicting response information and that both perceptually- and memory-based conflicts appear to enlist the activity of the same medial frontal brain circuits. Note that it is impossible to determine from our results whether activity in these brain networks was involved in monitoring for response conflicts, inhibiting the execution of the pre-potent response, or both. However, in accord with previous results (Turken & Swick, 1999; Van Veen et al., 2001), these response conflicts were processed by patterns of brain activity that differed from those used to process conflicts regarding proper stimulus categorization (i.e., the old-new differences).

A recent episodic memory study with results relevant to ours is one in which the degree of retrieval interference was manipulated. Herrmann et al. (2001) had participants learn two lists of words to 100% criterion. The words were concrete nouns from six semantic categories. To create conflicting response information, the lists were constructed such
that the words for each were drawn from four unique semantic categories and two overlapping categories (i.e., words for both lists were drawn from these same two categories). At test, the words from both lists were presented together, along with new words that were not from the same semantic categories. The participants’ task was to press one button for target words (items from one list) and the other for both the memorized distractors (items from the other list) and the new words. The response interference created by words on the distractor list from the overlapping semantic categories could be considered analogous to that created by making deceptive responses in our Consistent Deceptive condition.

Not surprisingly, the behavioral results of their study were similar to ours in that decisions about the target and distractor words from the overlapping categories were slower and less accurate than decisions about target and distractor words from the unique semantic categories. Herrmann et al. (2001) also found that ACC blood flow increased when there was increased response interference caused by the overlapping categories, similar to our finding of larger MFNs when increased response interference was caused by the pre-potent truthful responses in the deception conditions. Taken together, these data thus further reinforce the idea that the resolution of conflicting response information is handled by a general-purpose processor.

One interpretation of the present results, consistent with the idea that the ACC is a multi-functional area (Bush, Luu, & Posner, 2000; Swick & Jovanovic, 2002; Turkam & Swick, 1999), is that there was a “baseline” pattern of medial frontal activity for situations in which the conflict is primarily about the correct categorization of the stimulus (Perceptual Compatible and Consistent Truthful conditions). The output of this “baseline” pattern of MFN activity was most prominent at central sites (i.e., Cz). Our finding of greater MFN activity during memory retrieval (Consistent Truthful) compared to that for perceptual discriminations is in accord with results from imaging studies showing increased ACC blood flow in word recognition paradigms (e.g., Henson, Shallice, & Dolan, 1999; Herrmann et al., 2001; Nyberg, Habib, & Hultsch, 2000; Saykin et al., 1999; Wagner, Desmond, Glover, & Gabrieli, 1998). When the compatible response had to be inhibited and an incompatible response executed, a second medial frontal pattern of activity was recruited, presumably to resolve these conflicts. Then, when it was necessary to monitor strategically one’s responses, a third medial frontal pattern of activity was evident for both truthful and deceptive trials. Note that overall MFN amplitude recorded at any location depends on the summation of the outputs of the activated neural generators and this sum is unlikely to be entirely linear in all cases given that it depends on, among other factors, the relative orientations and strengths of the different neural generators. Finally, the fact that all three patterns of MFN generator activity were essentially simultaneous indicates that processing of these three types of information were conducted largely in parallel, independently of differences in task difficulty.

Because deceptive responses are a type of erroneous response, the question arises as to whether the MFNs elicited by the correct deceptive responses are the same as the error-related negativity (ERN; Dehaene et al., 1994; Gehring et al., 1993, 2000; Liotti et al., 2000; Milner et al., 1997). Although we emphasized knowing the home list well, when averaged over subjects and condition repetitions there were sufficient error data in some participants to make some tentative conclusions. A comparison of the ERNs elicited on error trials with the MFNs elicited on correct trials in the Consistent Truthful condition revealed that the ERNs were considerably larger, although still at the same latency. Only the MFNs elicited in the Random Deceptive condition approached the amplitude of the ERNs. To determine the relative locations of the ERN and MFN generators, we used a standard source-localization technique. Although the BESA source localization program automatically located the source of the error ERN in roughly the same medial frontal area as reported previously (Dehaene et al., 1994; Gehring et al., 2000; Liotti et al., 2000; Milner et al., 1997), the MFNs were all automatically located in a different medial frontal area, about 1.6 cm more posterior and 1 cm more superior to the location of the ERN generator. Thus, although based on limited data, our results suggest that different medial frontal areas are active as a function of whether participants make intentional or unintentional errors. These findings are in accord with those of a recent study that identified neuroanatomically separable ERN and MFN generators for error processing and conflict monitoring, respectively (Ulspeter & Von Cramon, 2001). In sum, the present results confirm and extend the distinctions between the MFN and ERN components and support the idea that the MFN reflects action monitoring processes (e.g., Gehring & Willoughby, 2002), rather than the error correction processes believed to be the basis of the ERN (see Holroyd & Coles, 2002 for a review), particularly given that our participants made “erroneous” responses deliberately which they had no intention of correcting.

4.3. Relation of deception to false memories and directed forgetting

All successful dependencies depend on timely and efficacious retrieval of information from memory, without which an incompatible response could not be generated. Thus, although the emphasis in the present study was on the mechanisms underlying the generation of incompatible responses, at least some of the results can be related to those of studies of the mechanisms underlying accurate and inaccurate retrieval of long-term memories. For example, responses in directed forgetting and false memory studies can be seen as being roughly analogous to the deceptive responses elicited here for old and new words, respectively. Various accounts have been advanced to explain false memories and confabulations, most of which involve some kind of failure in the constructive processes used during memory retrieval to
monitor the accuracy of retrieval results (e.g., Burgess & Shallice, 1996; Dab, Claes, Morais, & Shallice, 1999; Melo, Winocur, & Moscovitch, 1999; Moscovitch & Melo, 1997; Schacter, 1996). Like the executive processes described here, these memory retrieval monitoring processes are believed to depend on frontal lobe structures. Studies of the ERP activity associated with episodic retrieval have revealed differential patterns of brain activity depending on the study status of the items being recognized (see Friedman & Johnson, 2000; Johnson, 1995; Rugg & Allan, 2000 for reviews). To date, a number of aspects of this so-called “old/new” or “episodic memory” (EM) effect have been found in stimulus-locked ERP averages that differ in their spato-temporal characteristics. The best studied EM differences consist of a reduced negativity for old items over left frontal scalp between 300 and 500 ms, an enhanced late positive component for old items over left parietal scalp between 500 and 800 ms and a slightly greater slow positivity for old words over right frontal scalp that begins roughly 800–1000 ms after stimulus onset and continues for hundreds of milliseconds. Based on the results of numerous experiments, a general conclusion is that the left frontal and left parietal aspects of the EM effect reflect processes related to familiarity and recollection, respectively, whereas the long-lasting right frontal activity reflects post-retrieval processes (e.g., monitoring the source of the old item) (Friedman & Johnson, 2000; Rugg & Allan, 2000). The stimulus-locked averages for this data set (Johnson et al., 2003) revealed that, despite the fact that the old and new words were misclassified in the Consistent Deceptive and Random Deceptive conditions, the magnitude of the parietal EM effect was not significantly reduced compared to that elicited in the Consistent Truthful condition. Thus, the aspect of the parietal EM effect most closely identified with recollective processes was unaffected by whether participants denied having particular items in their memory that were in their memory or confabulated that they knew items that they did not know. We also note that the old/new MFN amplitude differences found here have different temporal and spatial characteristics from the previously identified left and right frontal aspects of the EM effect and its 100 ms duration is also briefer than any previously described aspect of the EM effect. Hence, these MFN memory status differences possibly represent a new aspect of the EM effect.

Given that deceptions depend on accurate retrieval of information from memory, it follows that the deceiver must be conscious of the retrieved memories in order to be able to generate an incompatible response. In this context, although not manipulated here, source monitoring processes (Johnson, Hashtroudi, & Lindsay, 1993; Mitchell & Johnson, 2000) are likely to play a larger role in memory retrieval for deceptive responses compared to truthful responses. Source memory is the term used to describe the memories for the conditions under which a particular memory is acquired and it is associated with the conscious recollection of one’s autobiographical experiences (Johnson et al., 1993; Mitchell & Johnson, 2000). Hence, source monitoring processes likely play an important role in all deceptions about past events by helping to ensure that the retrieved item correctly fits the circumstances about which the person is being deceptive. Hence, failures of source monitoring, or even ineffective monitoring, could lead to inconsistent lies or unintended truth-telling.

One method designed to study the relative contributions of conscious and unconscious processes to memory retrieval is the process dissociation procedure (PDP; see Kelley & Jacoby, 2000 for a recent review). The PDP has participants make old/new judgments about previously learned and unlearned items in the context of an inclusion and an exclusion condition. In the inclusion condition, designed to reveal the combined effects of conscious and unconscious memory processes, participants simply press that old items are old. However, when presented with old items in the exclusion condition, participants must withhold their response that the item is old and produce a different response. For example, when confronted with a word stem corresponding to a word on the learned list, the participant must inhibit that response and respond with a different word that would also complete the stem. Hence, the inclusion and exclusion conditions are roughly analogous to our Consistent Truthful and Consistent Deceptive conditions, respectively. Although no ERP memory studies have investigated MFN activity in a PDP paradigm, based on the differences between the Consistent Deceptive and Consistent Truthful conditions found here, we would predict greater MFN activity in the exclusion condition relative to the inclusion condition.

Directed forgetting paradigms create another situation that is similar to what may occur when deceptive responses are made about experienced items. In these experiments, participants are exposed to two sets of intermixed items with instructions to forget the items in one of the two sets. Hence, directed forgetting can be thought of as a conscious process intended to inhibit a response that the item is known, analogous to what must occur in the Consistent Deceptive condition. In their directed forgetting study, Ullsperger, Mecklinger, and Müller (2000) found that, unlike the to-be-remembered items, the to-be-forgotten items did not elicit the recollection-related parietal EM effect. However, they also reported that the to-be-forgotten items elicited a normal left frontal EM effect suggesting that these items were experienced correctly as being familiar. Nevertheless, although a normal left frontal EM effect was common to both their and our paradigm, the lack of recollection-related processes during directed forgetting means that this retrieval is fundamentally different from what must occur in any successful deception. This is not too surprising given that there are a number of differences between the directed forgetting and the deception paradigms. One main difference is the fact that, unlike in directed forgetting, it is the participant, rather than the experimenter, who decides which information needs to be inhibited in a deception.
Another topic of study in the memory literature that is somewhat analogous to what occurs in deception is that of false memories. These memories are defined as occurring when persons claim incorrectly that they have previously experienced some item or event. Given that both false memories and deceptive responses result in new words being falsely categorized as old, there may be a common mechanism underlying both types of responses. One method of generating false memories about items that were not experienced previously is with the Deese–Roediger–McDermott paradigm (e.g., Roediger & McDermott, 1995, 1996; Schacter, 1996). In this paradigm, participants are presented with a list of items that are strongly related semantically to a “lure” item, without actually receiving the lure. The typical result is that, when given a memory test, participants falsely classify the new lure items as old (e.g., Roediger & McDermott, 1995, 1996; Schacter, 1996). To date, only one ERP study has investigated the ERN activity elicited by false memories (Nessler & Mecklinger, 2003). These authors reported that larger ERNs were elicited by false memories compared to true memories at the central, Cz, site, with no difference at the frontal, Fz, site. Thus, although similar to our finding of larger MFNs for deceptive responses, the large apparent distributional differences between their ERNs and our MFNs suggest that the same cognitive processes were not used in both paradigms. Similarly, although most ERP studies of false memory quantified retrieval-related LPC activity, the findings of these studies are only somewhat consistent with the LPC results from the present study (Johnson et al., 2003; Johnson et al., submitted for publication). That is, whereas some experiments found that false memories elicited a parietal EM effect similar to that for true memories (Fabiani, Stadler, & Wessels, 2000; Nessler & Mecklinger, 2003), it was significantly smaller in most studies (Curtan, Schacter, Johnson, & Spinks, 2001; Gonsalves & Paller, 2000; Miller, Baratta, Wynveen, & Rosenfeld, 2001; Nessler, Mecklinger, & Penney, 2001). The findings of a significantly reduced parietal EM effect in the false memory studies, but not in our deception conditions, likely reflects the fact that, because all our old items had been experienced multiple times over the preceding week, our participants were readily able to distinguish them from new words when they were making deceptive responses.

Because false memories occur inadvertently, rather than deliberately, they are typically elicited under circumstances that are quite different from those in which deceptions occur. Hence, one fundamental difference between responses in the false memory and deception paradigms is that of intent. Indeed, most definitions of false memories and confabulations include the idea that these memory errors are unintentional and even unknown to the person who commits them (Burgess & Shallice, 1996; Melo et al., 1999; Moscovitch & Melo, 1997). This is consistent with our results showing that the MFNs elicited by deliberate errors (i.e., deceptions) and the ERNs elicited by inadvertent errors were generated in different medial frontal areas. Moreover, in Moscovitch and Melo’s (1997) view, confabulations can only occur if the monitoring process is defective. This is quite different from what occurs in deception, the success of which depends entirely on the person’s ability to accurately monitor and verify the true source of the memory trace. In fact, no successful deception can occur if these monitoring processes are defective because the selection of a deceptive response depends on the correct identification of the truthful response. There also appear to be differences in the anatomical basis of false memories and deceptive responses because, in contrast to the apparent role of the ACC in deception, Moscovitch and Melo (1997) localized strategic retrieval processes to ventromedial frontal cortex.

Another question concerns the extent to which the strategic response monitoring processes used in the Random Deceptive condition are similar to the strategic monitoring processes hypothesized to aid episodic memory retrieval. Strategic monitoring processes have been posited to play a role in helping to locate and verify that the retrieved memory is correct in a given situation (e.g., Burgess & Shallice, 1996; Henson et al., 1999; Melo et al., 1999; Moscovitch & Melo, 1997), with the failure of these retrieval control processes being linked to memory disorders (e.g., confabulations) (Johnson et al., 1993; Mitchell & Johnson, 2000; Melo et al., 1999; Moscovitch & Melo, 1997). For example, one component of Burgess and Shallice’s (1996) model of memory retrieval is “mediator processes” that control the determination of whether retrieved memory “elements” are plausible given the search criteria. Because Burgess and Shallice conceptualized these mediator processes as belonging to a complex set of problem-solving routines, not limited to processing mnestic information, it is possible that these same processes are used for strategic monitoring operations in the Random Deceptive condition. For example, the large medial-frontally generated MFNs elicited in the Random Deceptive condition are consistent with the posited role of the frontal lobes in these strategic processes. Unfortunately, on the basis of the present results, there is no way to gauge the extent to which the strategic monitoring processes might have contained a memorial component because this manipulation was not used in conjunction with the perceptual stimuli.

Nevertheless, there is an aspect of the ERPs elicited here that may reflect the use of strategic monitoring processes. That is, over central-frontal scalp in the interval prior to the response (i.e., from −400 to −100 ms), there was a memory-status dependent negativity. Although elicited by all words during recognition, this earlier negativity was larger for items not in episodic memory (i.e., new words; see Figs. 3–5) compared to that elicited by old words. Presumably this is due to the fact that items in memory would require less checking by the mediator processes than items not in memory. Supporting this interpretation, the amplitude of this pre-response negativity differed as a function of memory status, but not as a function of whether truthful or
deceptive responses were subsequently made. In this way, the activity of this negativity was opposite that of the MFN, which showed large variations as a function of response compatibility. The timing of this negativity, coming shortly before the response, is also consistent with the fact that response selection must be based on the retrieval results. Note that the central–frontal scalp distribution of this negativity is also consistent with the idea that strategic retrieval processes depend on the frontal lobes (e.g., Burgess & Shallice, 1996; Moscovitch & Melo, 1997) and it is very similar to the distribution of the MFNs elicited in the deceptive conditions. Thus, the present results leave open the possibility that mediator processes are used, at different times, during both memory retrieval and strategic response monitoring.

5. Conclusions

The present approach evaluated deceptive responses under rather restricted conditions in order to isolate some of the cognitive processes associated with making deceptive responses. For example, as in past studies (Allen, 2002; Allen & Iacono, 1997; Allen & Movius, 2000; Allen et al., 1992; Farwell & Donchin, 1991; Furedy et al., 1988; Johnson & Rosenfeld, 1992; Rosenfeld et al., 1996, 1998, 1999), deceptive responses were only simulated since both the participants and the experimenter knew the truth and the participants knew that. However, the apparent lack of behavioral or electrophysiological differences between the perceptually-based and memory-based response conflicts supports our contention that the executive processes required to make a conflicting response are an essential component of all deceptions. The Random Deceptive condition did provide a somewhat more realistic simulation because the participants determined, according to their own criteria, whether to respond truthfully or deceptively on any given trial. Nevertheless, neither of these situations likely engendered any emotional component, a normal aspect of deception. Based on the present results, it is reasonable to expect that studies of more realistic deceptions would reveal additional differences, such as those related to the intent to deceive and/or the emotional components of deception. However, such additional processes may also depend, at least to some extent, on the ACC since Fredrikson et al. (1998) showed that the ACC is part of circuit that controls electrodermal responding. It is possible, therefore, that the MFNs elicited during deceptive responding here may be precursors to the autonomic responses documented previously to occur when persons are deceptive (Vincent & Furedy, 1992).

Taken together, our results indicate that, although deception is a complex process, making deceptive responses appears to involve at least two electrophysiologically dissociable, general-purpose cognitive processes that are implemented by different patterns of medial frontal brain activity. One interesting aspect of our results is that the data from the Consistent Deceptive condition clearly indicate that any attempt to respond deceptively about whether information resides in one’s memory, even with a rapid and/or well-practiced response requiring no special planning, produces significant changes in both RT and MFN amplitude and scalp distribution. Thus, our results suggest that it should be possible to detect when persons respond deceptively because the brain apparently automatically and continuously monitors one’s actions for the purpose of preventing just such inappropriate responses.

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References


