The Detection and the Neural Correlates of Behavioral (Prior) Intentions

Sara Agosta[1,2], Umberto Castiello[2], Davide Rigoni[2], Stefano Lionetti[2], and Giuseppe Sartori[2]

Abstract

■ Prior intentions are abstract mental representations that are believed to be the prime cause of our intentional actions. To date, only a few studies have focused on the possibility that single prior intentions could be identified in people's minds. Here, for the first time, we used the autobiographical Implicit Association Test (aIAT) in order to identify a specific prior intention on the basis of a pattern of associations derived from reaction times (Experiment 1). The aIAT is based on two critical blocks: the block associating intentions with true sentences (congruent block) gave rise to faster reaction times (RTs) than the block associating intentions with false sentences (incongruent block). Furthermore, when comparing intentions with hopes, it was revealed that the reported effect was intention-specific: The pattern of associations reflected a congruency effect when intentions and the logical category "True" were paired, but not when hopes and the "True" category were paired (Experiment 2). Finally, we investigated the neural bases of the congruency effect that leads to the identification of an intention (Experiment 3). We found a reduced late positive component (LPC) for the incongruent with respect to the congruent block, suggesting that the incongruent block needs additional resources of cognitive control with respect to the congruent block. ■

INTRODUCTION

On arriving at the airport in Portland, Maine, USA, on Tuesday, September 11, 2001, Mohamed Atta had his terrorist plan already hidden somewhere in his mind. We suggest that he already had the intention to hijack the American Airlines Flight 11. In contrast, when the French soccer World Cup finalist Zinedine Zidane head-butted the Italian player Marco Materazzi in reaction to an offense, it is suggested that he did not have a similar, planned intention. Criminal law and soccer referees evaluate the level of intentionality of acts and they classified these two types of behaviors differently. The first type of behavior is characterized by a fully organized plot, and should be classified differently from the second type of behavior, which in sport jargon is indicated as "retaliatory fault."

Deliberation of a future action is called, in one terminology, prior intention (Searle, 1983). Prior intentions include goal-related processing and deliberate conscious intentions that are intuitively believed to be the leading cause of our future behaviors (Cohen & Levesque, 1990; Bratman, 1987). In other words, these are mental representations, which occur prior to the action itself and are typically believed to cause the action subjectively. Searle (1983) refers to prior intentions as the initial representation of the goal of an action prior to the initiation of the action: a type of intention that is formed in advance of a deliberate plan for a future action. In contrast, an intention in action (also termed motor intention) is the proximal cause of the physiological chain leading to an overt behavior. When a subject has the intention (i.e., the prior intention) to perform an action, there will be many subsidiary actions that will not be represented in the prior intention. In executing a well-practiced action sequence (e.g., driving a car towards the workplace), only the major headings are likely to be represented within the conscious intention (e.g., arriving at the workplace, parking, and entering the office); the details of the action sequence are unnecessary in advance (e.g., opening the car, finding a good place to park, turning the key, and opening the office). It might be said that a prior intention is the mental representation of the main goal of an action prior to the initiation of the sequence of actions leading to the achievement of the goal.

Other scholars have addressed a possible distinction between long-term antecedents of action (prior intentions; Searle, 1983) and short-term antecedents of actions (intentions in action; Sartori, Becchio, Bulgheroni, & Castiello, 2009; Becchio, Sartori, Bulgheroni, & Castiello, 2008a, 2008b; Searle, 1983). Long-term antecedents have also been named "prospective intentions" (Pacherie & Haggard, 2010), "distal intentions" (Pacherie, 2008), and "future-directed intentions" (Bratman, 1987). Although these proposals do not exactly overlap, they are all concerned with a volitional dimension, which is largely antecedent to the intended action. In order to identify the proper means for

[1]Instituto Italiano di Tecnologia, Rovereto, Italy, [2]University of Padua, Italy

the intended goals, the volition/deliberation phase might be preceded by reasoning and planning. Such a phase might end with a conscious overt deliberation. Short-term antecedents (i.e., intention in action; Searle, 1983) have also been termed as "proximal intentions" (Pacherie, 2008). Proximal Intentions are believed to inherit an action plan from the "distal intentions" phase and to adapt to such a plan for the action, which is then represented at the "motor intentions" level, a stage that might correspond to a motor representation (Becchio et al., 2008a, 2008b). A slightly different analysis, which does not exactly match the distal–proximal–motor distinction, has been proposed by Gollwitzer (1993, 1999). This author distinguishes between "goal intentions" and "implementation intentions" with the latter assisting in the achievement of the goal and taking the following hypothetical/deductive form: "If situation Y arises, then I will initiate goal-directed behavior Z" (Gollwitzer, 1999). For the sake of clarity, from now on, "long-term antecedents of action" will be termed "prior intentions" or simply "intentions."

Whereas motor intentions have attracted considerable attention in neuroscientific research (e.g., Becchio et al., 2008a, 2008b; Soon, Brass, Heinze, & Haynes, 2008; Lau, Rogers, Haggard, & Passingham, 2004; Haggard & Eimer, 1999; Libet, Gleason, Wright, & Pearl, 1983), few investigation has been conducted into prior intentions. A typical empirical evaluation of prior intentions includes ratings or meta-cognitive modeling, such as for the behavioral intention model (e.g., Fishbein & Ajzen, 1975). Here, prior intentions are estimated by asking subjects to rate the intensity of their intention on a rating scale. In this view, planned behavioral intentions (which are prior intentions) are considered to be the result of both beliefs and the subjective norms, which are relevant for the intended behavior. This approach is grounded on a subjective evaluation of the participant regarding the strength of the intention itself.

When evaluating prior intentions, a distinction between "general attitudes" and "detection of a single intention" might be applied. With respect to general attitudes, neuropsychological research has focused on tasks that are aimed at evaluating a general ability called prospective memory rather than measuring the detection of specific prior intentions (McDaniel, Einstein, Graham, & Rall, 2004; Einstein, McDaniel, Williford, Pagan, & Dismukes, 2003). Prospective memory (Ellis, 1996) is, therefore, a form of delayed prior intention occurring when the subject has to retrieve a previously established intention. There is a direct link between prior intention and prospective memory. Prior intention is concerned with high-level rational guidance and monitoring of the action, which is kept alive in prospective memory up until the time comes to carry out this action. Prospective memory might be distinguished by being "time-based" or "event-based" (e.g., Einstein, McDaniel, Richardson, Guynn, & Cunfer, 1995). A time-based prospective memory requires the execution of a prior intention at a specific moment in time, whereas an event-based prospective memory takes place when a specific event occurs. Time-based prospective memory tasks involve remembering to perform an intended action at a certain time or after a particular amount of time has passed (e.g., remembering to take a drug or to make a phone call in the afternoon). Event-based prospective memory tasks are of primary interest here because they involve remembering to perform an intended action when an appropriate environmental cue is encountered. An example of an event-based prospective memory task is remembering to buy bread on the way home from work. In neural terms, Haynes et al. (2007) showed that it is on the basis of the level of activity detected within the medial and lateral prefrontal cortices that it is possible to identify which of two tasks (i.e., adding or subtracting two numbers) the subject intends to perform in the immediate future.

Here, we focused on what people intend to do in the medium (i.e., during the night) and long (i.e., their career plans) terms by administering a modified version of the autobiographical Implicit Association Test (aIAT; Sartori, Agosta, Zogmaister, Ferrara, & Castiello, 2008) to participants. The aIAT (Sartori et al., 2008) is a novel variant of the Implicit Association Test (IAT; Greenwald, McGhee, & Schwartz, 1998) that might be used to establish whether or not an autobiographical memory trace is encoded within the respondent's mind/brain. The aIAT is a reliable method, validated in both forensic and clinical settings (Sartori et al., 2008; Sartori, Agosta, & Gnoato, 2007), which has the ability to reveal factual knowledge regarding autobiographical events that are presented in a verbal format. More specifically, with the aIAT, it is possible to evaluate which of two alternative autobiographical events is true.

The aIAT includes stimuli belonging to four categories. Two categories are logical categories represented by sentences that are always true (e.g., I am in front of a computer) or always false (e.g., I am climbing a mountain) for the respondent and refer to the moment of testing. Two other categories are represented by alternative versions of an autobiographical event (e.g., I went to Paris for Christmas vs. I went to London for Christmas), with only one of the two being true. The aIAT requires the accomplishment of five classification blocks: three single classification blocks (true vs. false, Paris vs. London and London vs. Paris) and two critical double classification blocks in which stimuli for one logical category and one autobiographical event are responded to with the same button (e.g., left button = true and Paris; right button = false and London, and vice versa). Because the association of a truly autobiographical event with certainly true sentences should facilitate the response, the specific pattern of response times (RTs) for these two critical blocks indicates which autobiographical event is either true or false. The true autobiographical event is identified because, in one of the two double blocks, it elicits faster RTs when it shares the same motor response with true sentences. Because it has been demonstrated that the aIAT can accurately (91% accuracy) determine which of two autobiographical events is true, the aIAT might be considered a reliable memory detection technique (Sartori et al., 2008).

In the present article, the aIAT (Sartori et al., 2008) has been used to detect specific prior intentions. Here, rather than describing autobiographical memories, sentences were used to express prior intentions. Consequently, in such a situation, the congruent condition will pair sentences expressing the participant's prior intention (intention sentences) and true sentences, whereas the incongruent condition will pair sentences expressing a prior intention that the participant does not have (nontrue intention sentences) and true sentences. Given that the congruent condition has consistently been characterized by RTs that are faster than those for the incongruent condition (Sartori et al., 2008), prior intentions should, therefore, be characterized by faster RTs when paired with true sentences. Furthermore, we investigated the neural correlates of the processes underlying the congruence/incongruence effects. Here, we do not address the cognitive components involved in the unfolding of intention as done recently by Pacherie and Haggard (2010) and Pacherie (2008). Rather, we investigated the efficiency of the autobiographical IAT in detecting fully formed goals and intentions that had a strong feeling of commitment and had already been deliberated and were ready to be implemented. Testing was undertaken in the temporal proximity of the action itself (e.g., spending the night in Padua with testing occurring at 6 pm). In this manner, the intrinsic unreliability of future-directed intentions, which are exposed to counter-effects originating from the environment, was minimized.

An adapted version of the aIAT for detecting prior intentions was also administered to participants while recording their event-related potentials (ERPs). The aIAT effect is based on RT differences between an easy congruent block and a difficult, in terms of associations, incongruent block. When undergoing the incongruent block, participants have to inhibit the tendency to make an automatic overbearing response (i.e., classify, with the same motor response, true sentences and true intention sentences) and select a response which is in conflict with it (i.e., pressing two different keys, one for true sentences and one for true intention sentences). Thus, congruent and incongruent blocks are different in terms of cognitive control and the type of conflicting responses, which are needed to perform the task. The late positive component (LPC), also known as P300, is an ERP component that has been associated with conflicting responses. For example, it has been shown that the LPC decreases as the conflict increases (Doucet & Stelmack, 1999; Magliero, Bashore, Coles, & Donchin, 1984), and decreases when attentional resources are located to a secondary task (Kramer, Wickens, & Donchin, 1985; Israel, Chesney, Wickens, & Donchin, 1980; Israel, Wickens, Chesney, & Donchin, 1980). Furthermore, Johnson, Henkell, Simon, and Zhu (2008) and Johnson, Barnhardt, and Zhu (2003) showed that responses conflicting with the truth produced decreased LPC amplitudes. On the basis of these results, we expected that LPC amplitudes would be reduced while participants underwent the incongruent task rather than the congruent task.

The present article is structured as follows: Experiment 1 investigated whether or not it is possible to identify a prior intention on the basis of a pattern of reaction times. Experiment 2 dealt with the possibility of distinguishing intentions from hopes, and Experiment 3 investigated the neural bases of the identification of intentions.

EXPERIMENTS

Experiment 1: The aIAT Identifies Prior Intentions

Participants

A total of 22 undergraduate students of the University of Padua (6 men and 14 women; age range 18–26 years) volunteered for this study. All participants were healthy, had normal or corrected-to-normal vision, signed an informed consent form, and were debriefed at the end of the experiment. The participants were randomly assigned to either the sleep group ($n = 11$) or the job group ($n = 11$). The sleep group was tested for medium-term prior intentions (in which the participants intended to sleep for the incoming night), whereas the job group was tested for long-term prior intentions (the job/profession the participants intended to do).

Materials and Procedure

The participants for the sleep and job groups were neuropsychology undergraduates, tested in Padua in late afternoon. They were preliminarily requested to fill out a yes/no questionnaire regarding their prior intentions for the incoming night (e.g., *I plan to sleep in Padua tonight* vs. *I plan to sleep in Milan tonight*) and for their career planning (e.g., *I plan to become a neuropsychologist* vs. *I plan to become a lawyer*). This questionnaire included 10 medium- and long-term alternatives. All of the participants planned to sleep in Padua and all of them declared their intention to seek a position as a neuropsychologist. For each participant, an aIAT was built with intention sentences describing either their intention for the next night (sleep aIAT) or their intention regarding career planning (job aIAT), and nontrue intention sentences describing a prior intention that the participant did not have. A point worth noting here is that each participant was administered with a different aIAT built on the basis of individual intentions collected from the questionnaires. Each participant was randomly assigned to one of the two aIAT types (sleep vs. job). The computerized task consisted of five separate blocks of categorization trials (as illustrated in Figure 1).

For each trial, the stimulus sentence was presented in the center of the screen. The participants were requested

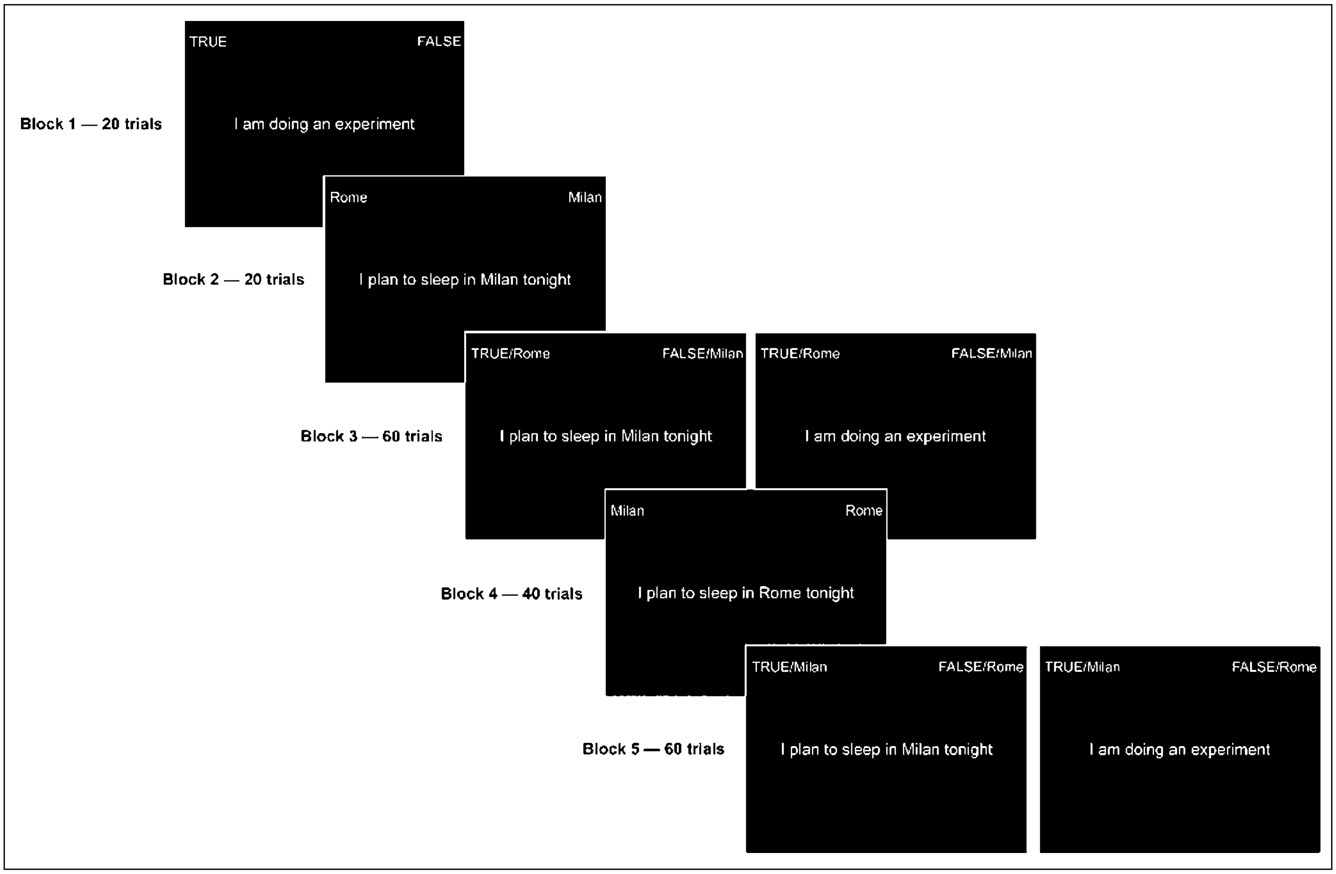

Figure 1. The experimental procedure of the aIAT is illustrated. Participants were requested to classify the stimulus (i.e., the sentences displayed) as fast as possible by pressing the correct key. In Block 3 (i.e., congruent block), stimuli describing true actions and intentions were assigned to the same response key (e.g., left key). In Block 5 (incongruent block), the same stimuli were assigned to a different response key (e.g., right key). In Blocks 3 and 5, only one sentence was presented at a time.

to classify the sentence as quickly and as accurately as possible by pressing one of two labeled keys, one on the right (i.e., key L) and one on the left (i.e., key A) of a keyboard. In Block 1 (20 trials), the participants classified stimuli along the logical dimension true versus false by pressing the left key if the sentence was true (e.g., *I am in front of a computer*) or the right key if the sentence was false (e.g., *I'm in front of a television*). In Block 2 (20 trials), the participants classified sentences along the critical dimension: intention versus nontrue intention. They classified sentences expressing a prior intention experienced by the participant (intention sentences; e.g., *I plan to sleep in Padua tonight*) with the left key and sentences expressing a prior intention that the participant did not have (nontrue intention; e.g., *I plan to sleep in Milan tonight*) with the right key. In Block 3 (60 trials, double categorization block), they were requested to press the left key if the sentence was either true or an intention, and the right key if the sentence was false or a nontrue intention (congruent block). In Block 4 (40 trials), the participants were requested to perform a reversed classification of Block 2: They pressed the left key for nontrue intention sentences and the right key for intention sentences. In Block 5 (60 trials, double categorization block), the participants pressed the left key for true sentences and nontrue intention sentences, and the right key for false sentences and intention sentences (incongruent block).

Reminder labels in the form of category names were displayed on the computer screen for the entire duration of the experiment. For the intention and nonintention categories, labels named either the location in which the participant would eventually sleep the following night (e.g., Milan vs. Padua) or the career that she or he was planning on pursuing (e.g., Lawyer vs. Psychologist), for the sleep and the job aIAT, respectively. An error signal appeared for 300 msec when an incorrect response occurred. The list of the sentences used in this experiment is provided in Table 1.

The crucial comparison (see Figure 1) was between mean RTs for the congruent and the incongruent blocks. The expected pattern of results should indicate faster RTs for the block associating intention with true sentences (congruent block) compared to the block associating nontrue intention with true sentences (incongruent block). The order of presentation for the congruent block (Block 3) and the incongruent block (Block 5) was counterbalanced across the participants for both the sleep and the job groups.

Table 1. List of the Sentences Used for All Three Experiments

Labels	*Italian Sentences*	*English Translation*
True	1. Sono di fronte ad un monitor	1. I'm in front of a monitor
	2. Sto rispondendo con la tastiera	2. I'm answering with the keyboard
	3. Sono seduto sulla sedia	3. I'm sitting on a chair
	4. Sto facendo un test di Psicologia	4. I'm doing a psychological test
	5. Sono in università	5. I'm inside the university building
False	1. Sono di fronte ad un televisore	1. I'm in front of a television
	2. Sto rispondendo con la matita	2. I'm answering with the pencil
	3. Sono seduto sulla panchina	3. I'm sitting on a bench
	4. Sto facendo un test di matematica	4. I'm doing a mathematical test
	5. Sono in ospedale	5. I'm inside the hospital building
Sleep in Padua	1. Questa sera dormirò a Padova	1. Tonight I plan to sleep in Padua
	2. Questa sera dormirò nel mio letto	2. Tonight I plan to sleep in my bed
	3. Questa sera dormirò nella mia stanza	3. Tonight I plan to sleep in my room
	4. Questa sera dormirò da solo	4. Tonight I plan to sleep alone
	5. Questa notte mi addormenterò a Padova	5. Tonight I plan to fall asleep in Padua
Sleep in Milan	1. Questa sera dormirò a Milano	1. Tonight I plan to sleep in Milan
	2. Questa sera dormirò sul divano	2. Tonight I plan to sleep on the sofa
	3. Questa sera dormirò con la mia ragazza/ragazzo	3. Tonight I plan to sleep with my girlfriend/boyfriend
	4. Questa sera dormirò a casa dei miei	4. Tonight I plan to sleep at my parents' place
	5. Questa notte mi addormenterò a Milano	5. Tonight I plan to fall asleep in Milan
Neuropsychologist	1. Ho intenzione di fare il neuropsicologo	1. I plan to be a neuropsychologist
	2. Intendo fare valutazioni neuropsicologiche	2. I plan to do neuropsychological evaluations
	3. Intendo diventare neuropsicologo	3. I want to be a neuropsychologist
	4. Somministrerò test neuropsicologici	4. I plan to administer neuropsychological tests
	5. Lavorerò con pazienti con danno cerebrale	5. I plan to work with patients
Lawyer	1. Ho intenzione di fare l'avvocato	1. I plan to be a lawyer
	2. Intendo diventare avvocato	2. I want to become a lawyer
	3. Mi occuperò di pratiche legali	3. I plan to deal with legal files
	4. Intendo occuparmi di cause legali	4. I plan to deal with lawsuits
	5. M'iscriverò all'albo degli avvocati	5. I plan to register as a lawyer
Graduation	1. Ho intenzione di laurearmi	1. I plan to graduate
	2. Conseguirò la laurea in Psicologia	2. I plan to graduate in psychology
	3. Ho intenzione di conseguire la laurea	3. I plan to achieve a degree
	4. Intendo laurearmi in Psicologia	4. I want to graduate in psychology
	5. Mi laureerò in Psicologia	5. I will graduate in psychology
Winning	1. Ho intenzione di vincere al gioco	1. I plan to win the lottery
	2. Intendo fare una vincita milionaria	2. I plan to win millions
	3. Intendo diventare ricco con una vincita	3. I plan to become rich winning the lottery
	4. Intendo vincere tanti soldi al gioco	4. I plan to win a lot of money
	5. Diventerò milionario vincendo al gioco	5. I plan to become a millionaire by winning the lottery

Table 1. (*continued*)

Labels	*Italian Sentences*	*English Translation*
Drawing blood	1. Ho intenzione di fare le analisi del sangue	1. I plan to take a blood test
	2. A breve farò le analisi del sangue	2. In a short time I will take a blood test
	3. Ho intenzione di fare un prelievo del sangue	3. I plan to draw blood
	4. Intendo fare le analisi sanguigne	4. I will undergo blood testing
	5. Intendo fare gli esami del sangue	5. I need to do a blood test
Padova	1. Intendo dormire a Padova	1. I plan to sleep in Padua
	2. Mi addormenterò a Padova	2. I plan to go to sleep in Padua
	3. Prenderò sonno a Padova	3. I plan to fall asleep in Padua
	4. Stanotte dormirò a Padova	4. Tonight, I'm going to sleep in Padua
	5. Stasera dormirò a Padova	5. Tonight, I plan to sleep in Padua
Milan	1. Intendo dormire a Verona	1. I plan to sleep in Verona
	2. Mi addormenterò a Verona	2. I plan to go to sleep in Verona
	3. Prenderò sonno a Verona	3. I plan to fall asleep in Verona
	4. Stanotte dormirò a Verona	4. Tonight, I'm going to sleep in Verona
	5. Stasera dormirò a Verona	5. Tonight, I plan to sleep in Verona

Dependent Measures and Data Analysis

Two dependent measures were considered: mean RTs for the double categorization blocks (3 and 5) and the D-IAT index (Greenwald, Nosek, & Banaji, 2003). Any RTs shorter than 150 msec or longer than 10,000 msec were discarded prior to any further analysis. The D-IAT index included a penalty for incorrect trials, and expressed the IAT effect (the difference in performance between the two double categorization blocks) in terms of the standard deviation of the latency measures. This was calculated by subtracting the corrected mean RTs for the congruent block from the mean RTs for the incongruent block. Then, this difference was divided by the inclusive standard deviation for the two blocks. The data were subjected to an ANOVA with Congruency (congruent vs. incongruent) as the within-subjects factor and Type of aIAT (sleep aIAT vs. job aIAT) and Order (Order 1 vs. Order 2) as the between-subjects factors. The D-IAT was analyzed by ANOVA with Type of aIAT (sleep aIAT vs. job aIAT) and Order (Order 1 vs. Order 2) as between-subjects factors.

Results and Discussion

A significant Congruency effect [$F(1, 18) = 70.578$, $p < .001$, $\eta_p^2 = 0.797$] indicated that average RTs for the congruent block were faster than for the incongruent block (1029 msec vs. 1741 msec). The significant Congruence × Type of aIAT interaction [$F(1, 18) = 9.340$, $p = .007$, $\eta_p^2 = 0.342$] indicated a larger aIAT effect (i.e., difference between incongruent and congruent blocks) for the sleep group than for the job group [$t(20) = -3.051$, $p = .006$]. No other interactions reached or approached a level of significance (all $p > .05$). The D-IAT for the sleep group was 1.30, whereas for the job group it was 1.02. The results for the D-IAT indicated that neither the main factors nor the interaction was significant ($p > .05$). The intentions of all participants were correctly detected using both RTs and the D-IAT (22/22 correctly classified). The correspondence between the analysis conducted on RTs and the analyses conducted on D-IAT was not complete. Such a lack of correspondence might have been due to the fact that the D index takes into account errors by assigning a 600-msec penalty to the RTs corresponding to errors. Figure 2 shows the RTs for the sleep and the job aIAT groups.

In order to corroborate these findings, we tested two further groups of participants. One group included six participants who did not intend to sleep in Padova, but who expected to sleep in Genoa. Another group of six participants attended law school (these participants clearly manifested their intention to start a career as lawyers). For these two groups, the nontrue intentions were "sleeping in Padova" and "becoming a neuropsychologist," which were the intentions of the two groups originally tested. The results were in parallel with those reported above. Also, the intentions of these participants were classified correctly on the basis of the D-IAT. There was a clear Congruency effect ($p = .003$) and a significant interaction between the medium-term intention (to sleep in Genova) and the long-term intention (to become a lawyer), with the IAT effect larger for the medium-term intention ($D = 1.13$) than for the long-term intention ($D = 0.375$) ($p = .008$).

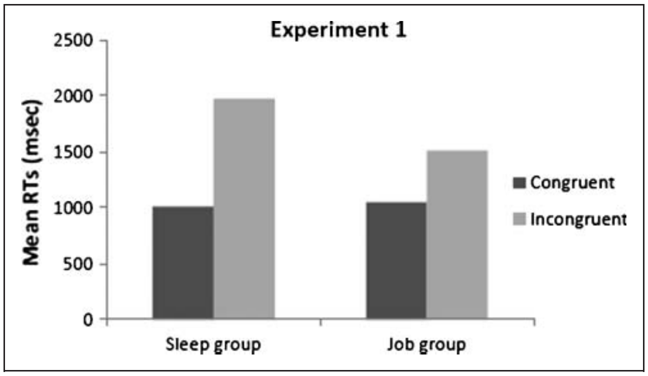

Figure 2. This figure shows the average RTs for the two groups considered in Experiment 1, the sleep group (medium-term intention) and the job group (long-term intention). The difference between the congruent and incongruent block was greater for the sleep group than for the job group.

Experiment 2: The aIAT Measures Prior Intentions but Not Hopes

In Experiment 1, we found that the categorization of sentences was facilitated when true sentences were paired with the same response key as intentions. We correctly identified the intentions of 22/22 of the participants on the basis of mean RTs for the double categorization block. However, Experiment 1 did not exclude the possibility that the aIAT identifies hopes (e.g., becoming a famous psychologist) rather than intentions (e.g., becoming a psychologist).

Intentions are different from hopes. Intentions are the aims for performing actions in the future (e.g., graduating in psychology), whereas hopes reflect a belief in a positive outcome (e.g., winning a lottery). Haggard (2005, p. 290) defined intentions as "several distinct processes within the chain of information processes that translate desires and goals into behaviour." Audi (1973, p. 388) distinguished intentions and hopes on the basis of their probability of occurrence: "to distinguish to bringing about Ø by doing A from merely hoping to bring about Ø by doing A, we need to require that x (the subject) at least believes his doing A will be a probable way to achieve Ø." By definition, an intention is believed to have a probable outcome, whereas a hope is believed to be uncertain (Audi, 1973). Furthermore, whereas intentions may also have an undesirable goal (e.g., going to the dentist, undergoing surgery), hopes have only desirable goals (e.g., winning a lottery) (Audi, 1973).

Intentions may vary in relation to the pleasantness of the associated goal. A goal can be highly pleasant (e.g., graduating in psychology) or unpleasant (e.g., going to the dentist), but both translate into actions aimed at their achievement (i.e., if subjects want to graduate, they have to pass all of the exams, write a thesis, etc.; if subjects want to go the dentist, they have to call for an appointment). In Experiment 1, the participants might have been faster in associating true sentences with intention sentences just because the intention sentences reflect a hope, rather than a real intention, which might be translated into action. Therefore, in Experiment 2, we compared prior intentions and hopes. Intentions were distinguished on the basis of the pleasantness of the goal. In sum, in the present experiment, we contrasted intentions with pleasant goals, intentions with unpleasant goals, and hopes for all of the three possible combinations. If the aIAT identifies intentions and not simply hopes, then the facilitation pattern will show faster reaction times when true sentences share the same motor responses with intention sentences and not with hope sentences.

Participants

Thirty students (9 men and 21 women; age range 19–30 years) from the University of Padova volunteered for this study. They were randomly assigned to one of the three conditions. For all of the conditions, the order of the double categorization blocks (congruent and incongruent blocks) was counterbalanced across the participants. The participants were assigned randomly to one of the groups described in Table 2.

Materials and Procedure

Prior to the experimental session, each participant was asked to answer a series of yes/no questions regarding 12 possible intentions (identified on the basis of the authors' intuitions). In particular, they had to indicate

Table 2. The Three Conditions Investigated in Experiment 2

Comparison	*Intentions with Pleasant or Unpleasant Outcome vs. Hopes*	*Example*	*No. of Participants*
1	Intention associated with pleasant outcome vs. Hope	Master's degree vs. Winnings	10
2	Intentions associated with unpleasant outcome vs. Hope	Medical control vs. Winnings	10
3	Intention associated with pleasant outcome vs. Intention associated with unpleasant outcome	Master's degree vs. Medical control	10

Each condition compares intentions (related to pleasant or unpleasant outcomes) and hopes for a total of three comparisons. In the table, each comparison is described in terms of a pleasant or unpleasant outcome, associated with the intention or as a hope.

whether they did or did not have a series of intentions, and whether the goals for these intentions were pleasant or not. An example of a pleasant goal was: *I will graduate in Psychology*. An example of an unpleasant goal was: *I plan to go to the dentist*. They were also asked to indicate whether they did or did not have a series of hopes (e.g., *I plan to win the lottery*). They were also asked to write examples of pleasant and unpleasant goals for each intention and hope, and to indicate whether the probabilities of achieving these goals were high or low. For each participant, two categories/items were chosen between pleasant outcome intentions, unpleasant outcome intentions or hopes, and a specific aIAT was implemented for each participant.

The aIAT procedure required the use of sentences belonging to the logical categories true and false, and sentences describing intentions that differed in terms of the outcomes of pleasantness or hope. The task consisted of five classification blocks, typical of any aIAT (Sartori et al., 2008). The aIAT was accomplished by asking the respondent to complete two critical double categorization blocks in which intentions or hopes (e.g., *I plan to graduate in Psychology* or *I plan to go to the dentist*) were associated with certainly true events (e.g., *I am in front of a computer*). An example of the sentences used is shown in Table 1.

In order to disentangle the critical issue of whether the aIAT effect can differentiate between intentions and hopes, three different comparisons were developed and three different aIATs were built. An example of each comparison is provided in Table 2.

Data Analysis

In this experiment, we wanted to demonstrate that the aIAT identifies intentions but not hopes. First of all, we contrasted the intentions associated with pleasant outcomes and hopes, then we contrasted the intentions associated with unpleasant outcomes and hopes, and finally, we compared both types of intentions associated with pleasant and unpleasant outcomes. Each comparison was analyzed separately. The RTs between 150 and 10,000 msec in the two critical double categorization blocks were subjected to ANOVA with the double categorization blocks (the type of intention or hope, which varied for each condition, was associated with true sentences) as the within-subject factor and the order of presentation of the double categorization blocks as the between-subject factor (Order 1 vs. Order 2).

The D-IAT results were subjected to a univariate ANOVA with order of presentation (Order 1 vs. Order 2) as the between-subjects factor.

Results and Discussion

The order of presentation of the blocks will not be discussed because it did not reach significance for any of the considered conditions. Figure 3 shows the RTs for each comparison. In the first comparison, the block pairing intentions related to a pleasant outcome and true sentences elicited RTs that were faster than those for the block pairing hopes and true sentences (1023 msec vs. 1518 msec, $p < .001$). The second comparison revealed faster RTs for the block pairing intentions related to an unpleasant outcome and true sentences than for the block pairing hopes and true sentences (956 msec vs. 1204 msec, $p = .03$). Even when the intention was related to an unpleasant outcome, it was strongly associated with the true category. The third and last comparison did not show any significant difference when comparing intention related to both a pleasant and an unpleasant outcome (1130 msec vs. 1222 msec, $p = ns$). Both outcome categories appeared to be represented by intentions, which, eventually, would be translated into actions.

The results indicated that for the D-IAT the main effects were not significant ($p > .05$).

Overall, these findings suggest that when contrasted with hope sentences, intentions with or without pleasant outcomes are strongly associated with true sentences. This indicates that the aIAT has the ability to distinguish between intentions and hopes. In contrast, when comparing the two intentions with differing outcomes in terms of pleasantness, no differences in the RT pattern were found. A possible explanation for this lack of effects might lie in the fact that if the aIAT encodes intentions and unpleasant outcomes, then both intentions are true, and therefore, potentially associated with true sentences. Taken together, the results from Experiments 1 and 2 showed that the aIAT identifies intentions and that such identification is not due to a confounding effect of pleasantness. In fact, high and low levels of pleasantness might not be distinguished on the basis of the aIAT.

Experiment 3: The Neural Correlates of Intention Detection Using the aIAT

Having demonstrated that the aIAT has the potential to decode intentions, we next investigated which neural mechanisms might subserve such a function.

Participants

Twenty-six undergraduate students of the University of Padua (10 men and 16 women; age range 19–30 years) volunteered for this experiment for a credit course. They were healthy and had normal or corrected-to-normal vision. All subjects signed an informed consent form and were debriefed at the end of the experiment. One participant was eliminated from the analysis because he failed to comply with the instructions. Therefore, the analysis considered 25 participants in total.

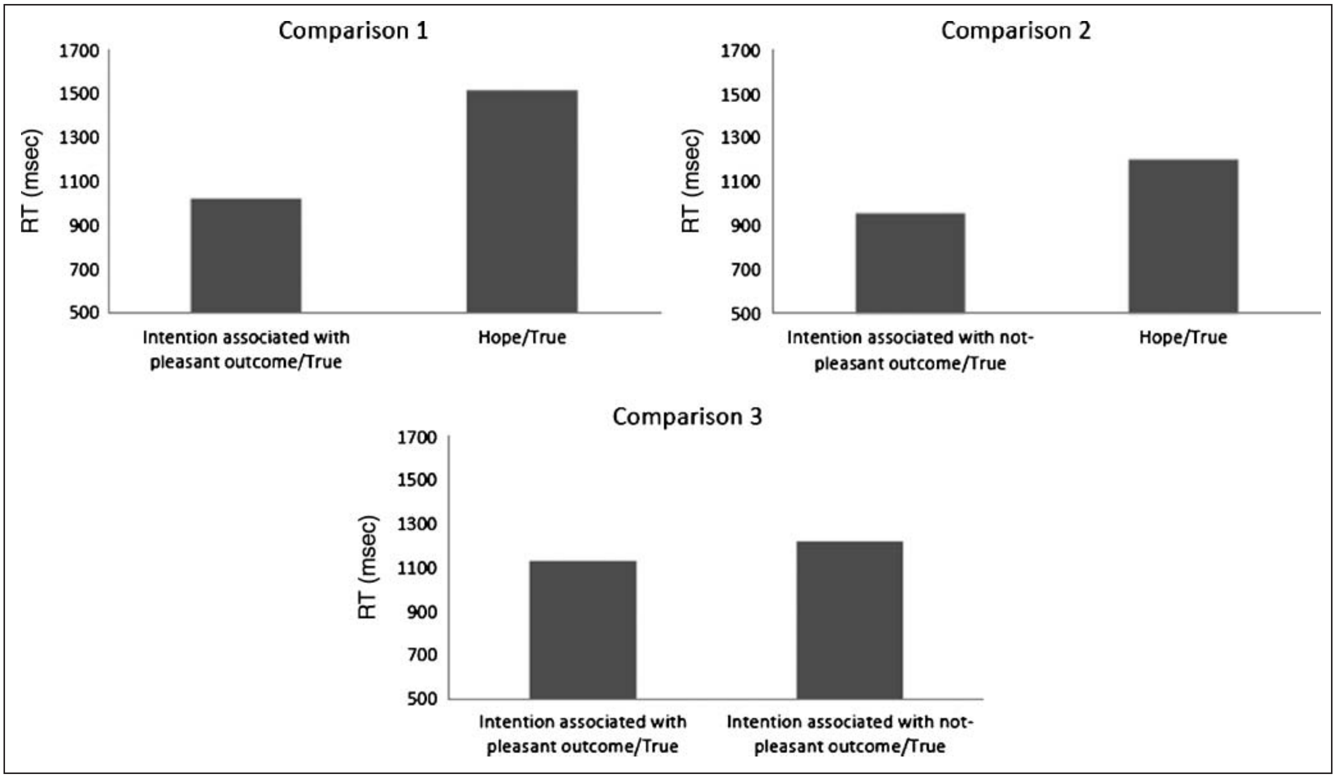

Figure 3. The average RTs for the three conditions analyzed. As highlighted here, the aIAT effect is due to a difference in the translation into action. Comparison 1 shows that when contrasting pleasant outcome intentions and hopes, intentions are more strongly associated with the concept of truth (i.e., RTs are faster). Comparison 2 shows the same result for unpleasant outcome intentions. For Comparison 3, we did not find any difference between the two types of intentions.

Materials and Procedure

The task adopted in Experiment 1 was modified in order to accomplish the requirements for an ERP experiment. The stimuli used in this experiment were 20 sentences describing intentions for the ensuing night (sleep-aIAT). True versus false sentences and intention versus nontrue intention sentences were all displayed, one word at a time, and each was the same length (5 Italian words each). The participants were requested to read each word carefully and to classify the sentence following the presentation of the last word (i.e., the target word) of each sentence. Each sentence of the true category (e.g., *I'm in front of a computer*) was matched with a sentence belonging to the false category (e.g., *I'm in front of a television*) so that they differed only for the last presented word. Each sentence for the intention category (e.g., *I plan to sleep in Padua*) was matched with a sentence for the nontrue intention category (e.g., *I plan to sleep in Milan*). In such circumstances, the two sentences differed only in terms of the last presented word. Each word was presented for 250 msec, with a 100-msec interval before the presentation of the following word. There was, however, one exception: The last word of each sentence remained on the screen until the subject provided a response.

In this experiment, the participants were administered with a greater number of trials than those administered in Experiment 1, in which the same paradigm was administered. This was done in order to enhance the signal-to-noise ratio of ERP recording. Blocks 1 and 2 consisted of 30 trials (each item was presented thrice). Blocks 3 and 5 consisted of 120 trials (each item was presented six times). The number of trials for Block 4 was 40 trials, as in the typical aIAT. Half of the participants were presented with the congruent block before the incongruent block (Order 1), whereas the other half were presented with the reverse order (Order 2). An example of the sentences used is provided in Table 1.

Electroencephalogram (EEG) Recording

Scalp voltages were recorded using a 59-channel electrocap with Ag/AgCl electrodes. A frontal electrode (AFz) was connected to the ground. During recording, all electrodes were referenced to mastoids. Vertical and horizontal eye movements were recorded. Electrode impedance was kept under 5 kΩ for all recordings. The EEG was recorded continuously and digitalized at a sampling rate of 500 Hz. The signal was off-line filtered using a low-pass filter for 30 Hz and 24 dB/octave attenuation. Ocular movement artifacts were corrected using the algorithm provided by the Neuroscan 4.3 software. The EEG was segmented into epochs starting 200 msec before presentation of the target word and lasting 1000 msec after its onset. The epochs were aligned to the 200-msec baseline before onset of the target word presentation. Trials contaminated by movement artifacts (peak-to-peak deflection over ±75 μV) were rejected before being averaged. The ERP were averaged for correct congruent and incongruent blocks. Approximately 5% of the trials were excluded from averaging because of movement artifacts.

Results and Discussion

Behavioral data. The two dependent measures for this experiment were the mean RTs (between 150 and 10,000 msec) and the D-IAT (Greenwald et al., 2003). A mixed ANOVA with Congruency (congruent vs. incongruent) as the within-subject factors and Order (Order 1 vs. Order 2) as the between-subject factor was performed. The RTs were measured starting from the presentation of the last word. The D-IAT (D600 scoring algorithm, see Greenwald et al., 2003) was calculated by subtracting the congruent block associating true sentences and intention sentences from the incongruent block associating true sentences and nonintention sentences. All individual D-IATs were subjected to ANOVA with Order (Order 1 vs. Order 2) as the between-subject factor.

With respect to the mean RTs, the result of the Congruency factor was significant [$F(1, 23) = 8.965$, $p = .006$, $\eta_p^2 = 0.280$]. The response latencies for the congruent condition were faster than those for the incongruent condition (669 msec vs. 728 msec), indicating a strong association between true sentences and intention sentences. Neither the Other main factors nor the interaction reached a significant level (all $p > .05$).

Using the D-IAT, we correctly classified 18/25 of the participants' intentions. The D-IAT ANOVA was not significant [$F(1, 23) = 0.029$, $p = .867$, $\eta_p^2 = 0.001$]. The lower level of accuracy, as compared with the level of accuracy reported in Experiment 1, might be ascribed to the stimuli presentation procedure used in the present experiment. The main difference between the procedure adopted in the present experiment and the procedures adopted in Experiment 1 was the word-by-word presentation of sentences, which leads to faster RTs.

Evoked related potentials results. The ERP analyses were only conducted on the participants who showed an association between the intention sentences and the true sentences (i.e., a positive D-IAT). We restricted the ERPs to these subjects because we wanted to analyze the pattern of congruency within the brain. Furthermore, two participants were discarded as they showed an average of 30% epochs with artifacts of movement. Sixteen participants were finally analyzed. Inspection of the ERPs indicated two different components. The first component was the N400, a negative wave that peaked in the interval between 300 and 500 msec (Sartori, Polezzi, Mameli, & Lombardi, 2005; Kutas & Hillyard, 1980), with maximal amplitude over parietal areas (Kutas & Federmeier, 2000). The N400 was quantified as the mean amplitude between 300 and 500 msec after the target word presentation for the true and false sentences considered in Blocks 1, 3, and 5. The N400 component was analyzed for true and false sentences only. The N400 mean amplitude was the dependent variable. A mixed ANOVA with site (P3 vs. Pz vs. P4) and truthfulness (true vs. false) as within-subject factors and order (Order 1 vs. Order 2) as the between-subject factor was performed.

The second component was the LPC, which was measured over the midline-parietal electrodes as in previous studies (Johnson et al., 2003, 2008; Qu, Wang, & Luo, 2008). Its amplitude was determined as the mean voltage between 350 and 650 msec following the target word onset for the congruent and the incongruent blocks (Blocks 3 and 5). A mixed ANOVA, with Site (Cz vs. CPz vs. Pz) and Congruency (congruent vs. incongruent) as within-subject factors, and Order (Order 1 vs. Order 2) as the between-subject factor, was performed with the mean LPC amplitude as the dependent variable.

Using data from a multiple electrodes site may lead to a violation of the sphericity assumption; therefore, all ANOVA results were corrected using the Greenhouse–Geisser procedure (Picton et al., 2000). Only correct answers were analyzed.

N400. The ANOVA yielded a significant main effect of Truthfulness [$F(1, 14) = 20.225$, $p < .001$, $\eta^2 = 0.591$], indicating a greater amplitude for false than for true sentences (3.5 μV vs. 1.4 μV). The Truthfulness × Site interaction was also significant [$F(1, 28) = 5.059$, $p = .013$, $\eta^2 = 0.265$], indicating a larger difference between true and false sentences in the central electrode compared to the right electrode [$t(15) = 3.433$, $p = .004$]. Figure 4 shows the N400.

Late positive component. The main factor of Congruency was significant [$F(1, 14) = 4.960$, $p < .05$, $\eta^2 = 0.262$], with smaller LPC amplitudes for the incongruent than for the congruent block (2.8 μV vs. 3.7 μV). None of the other effects reached or approached a level of significance (all $p > .05$) (Figure 5). This result highlights the necessity for greater cognitive control during the incongruent block with respect to the congruent block (Johnson et al., 2003).

The N400 is a classical wave related to semantic congruency. For example, words out of context elicit an N400 (Berkum, Hagoort, & Brown, 1999; Kutas & Hillyard, 1980). More recently, Hagoort, Hald, Bastiaansen, and Petersson (2004) showed that the N400 is also elicited when a false sentence is presented, meaning that "the brain retrieves and integrates word meaning and world knowledge at the same time" (Hagoort et al., 2004, p. 440).

In the present study, we found the same results by analyzing true (e.g., *I'm in front of a computer*) and false sentences

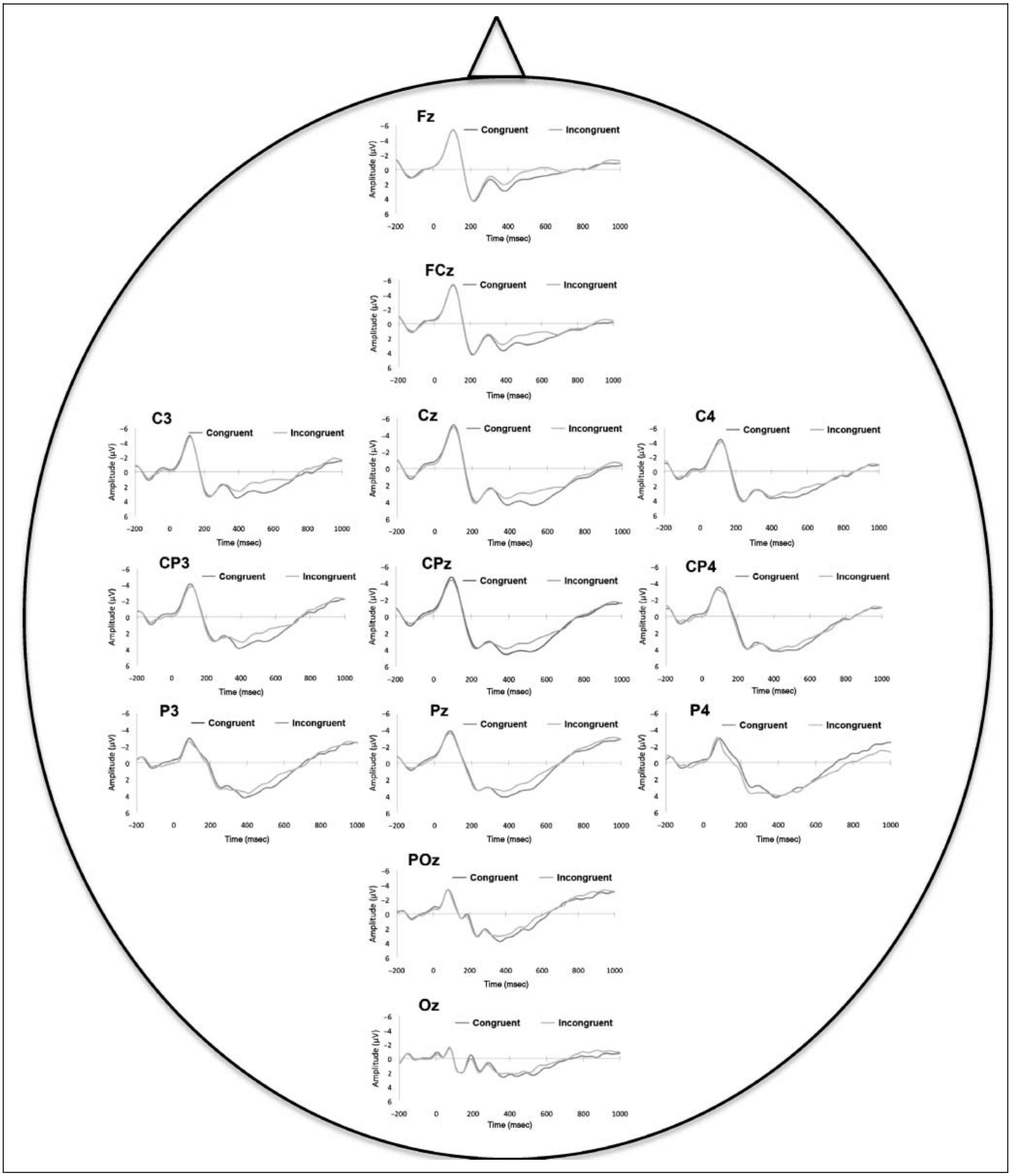

Figure 4. The N400 component in P3, Pz, and P4 sites. The N400 was larger for false than for true sentences.

(e.g., *I'm in front of a television*). We showed that false sentences elicited an N400 compared to true sentences.

In this respect, a point worth noting is that the N400 amplitude might be affected by the word frequency. Previous studies showed that low-frequency words elicit a larger N400 than high-frequency words (Van Petten & Kutas, 1991; Smith & Halgren, 1987). To evaluate this possibility, we considered the frequency of the last triggering word. For true sentences the average frequency of words was 59.2 (*SD* = 46.66), whereas for false sentences, the average frequency of words was 172.2 (*SD* = 299.99). In our case, the larger N400 was not driven by low-frequency words as we observed a larger N400 for false sentences ending with high-frequency words. Having said that, we are aware that such post-hoc analysis should be taken with a certain degree of caution.

Visual inspection of the ERP, comparing the intentions and nonintention stimuli, showed no differences. The N400 reveals semantic incongruency and detection of a false statement (Hagoort et al., 2004; Kutas & Hillyard, 1980). A possibility is that if the N400 signals semantic incongruency, then such incongruency should be revealed

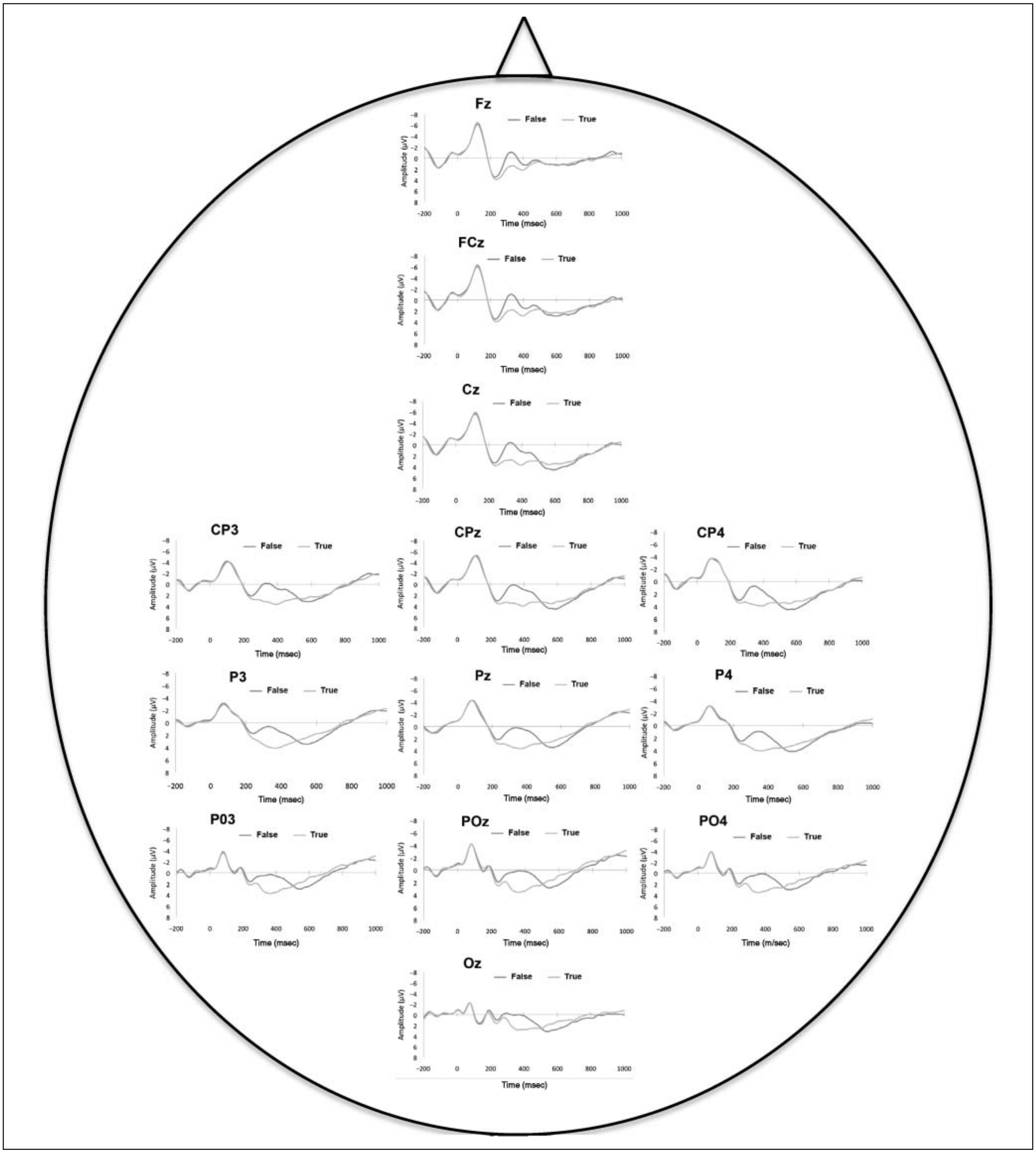

Figure 5. The late positive component in Cz, CPz, and Pz sites. The LPC amplitudes are smaller for the incongruent than for the congruent block in all three sites. The LPC is the signature for cognitive control. A smaller LPC indicates the need for greater cognitive control.

for the true/false classification, but not for the intention classification. Indeed, we found no effect on the N400 component regarding the intention versus nonintention classification. This might be because the intention type of classification occurs between Intention A and Intention B. We did not ask the participants to classify whether their intentions were true or false. A mixed ANOVA with Site (P3 vs. Pz vs. P4) and Type of Intention (intention vs. nonintention) as the within-subject factors and Order (Order 1 vs. Order 2) as the between-subject factor was performed. There were no main factors or interactions that reached significance ($p > .05$).

GENERAL DISCUSSION

The three studies reported in this article show that: (i) it is possible to identify a prior intention on the basis of the aIAT congruency effect (Experiment 1); (ii) intentions identified through the aIAT can be distinguished from hopes (Experiment 2); (iii) the pattern of congruence/incongruence detected by the aIAT has its neural bases on the LPC (Experiment 3).

We showed that prior intentions can be reliably identified by using the aIAT (Sartori et al., 2008). The aIAT has been primarily used to identify a true past autobiographical event (e.g., a past vacation) from between two events. This is the first time in which the aIAT has been administered to identify a future medium and a long-term prior intention. Previously, Haynes et al. (2007) showed that it was possible to decode which of two tasks was intended to be performed in the immediate future (adding or subtracting two numbers) on the basis of a pattern of medial and lateral prefrontal activity. Here, we extend this notion to the possibility of identifying intentions on the basis of a pattern of congruency on the basis of reaction time latency for medium- and long-term intentions.

We also examined whether or not intentions and hopes can be distinguished. In order to answer this critical question, we compared intentions and hopes at the level of pleasant and unpleasant outcomes. Our findings provide compelling evidence that intentions have a stronger association with "true" sentences with respect to hopes. Although both intentions and hopes are subjective and internal experiences, the former involve a higher level of control (Ajzen & Madden, 1986) as they are associated with a form of control over factors affecting the achievement of the goal. In contrast, hopes do not imply a control over such factors. To speculate, the "control" function is indeed what seems to be detected by the aIAT; what is mostly associated with the concept of truth is what is going to be translated into actions and behaviors (i.e., intentions).

We finally investigated the neural bases of the aIAT. The ERP analysis consistently revealed a different waveform for congruent and incongruent categorizations. Incongruous associations showed a smaller, late positivity component compared to congruous associations in the time window between 350 and 650 msec poststimulus.

Previous studies reported smaller LPCs when conflicting response information was introduced into the task (Doucet & Stelmack, 1999; Magliero et al., 1984). Moreover, a series of studies demonstrated that the LPC associated with a primary task decreased when attentional resources were allocated to a secondary task (Kramer et al., 1985; Wickens, Kramer, Vanasse, & Donchin, 1983; Israel, Chesney, et al., 1980). In recent studies, Johnson et al. (2003, 2008) investigated truthful and deceptive responses to perceived and memorized stimuli. They observed that responses conflicting with the truth produced a reduced LPC. In this perspective, the incongruent block in our task is based on inhibition of the correct answer. This answer is automatically processed and associated with the concept of "truth" and is then based on the production of the opposite response. Consequently, if a subject is engaged in a performance for the incongruent task, additional processing resources are needed. Using these extra control processes is equivalent to engaging in a *secondary task* that the person has to perform in addition to the primary task—answering the truth. All these data support the idea that the LPC may be a signature of the "response conflict" process.

Here, we confirm these previous observations by revealing a smaller LPC for the incongruent block, in which intentions are associated with false sentences, than for the congruent block, in which intentions are associated with true sentences. This indicates the need for additional control while performing the incongruent block.

Practical applications of this method may involve all fields in which intention evaluations are a key issue, such as clinical and forensic assessments. The validation of suicidal intention is typically difficult to evaluate clinically (e.g., Beck, Kovacs, & Weissman, 1979). This method might help in attributing seriousness to overtly claimed suicidal intentions as well as to hidden deceived intentions. In the United States in 2006, suicide was the 11th leading cause of death, accounting for 33,300 deaths. The overall rate was 10.9 suicide deaths per 100,000 people and an estimated 12 to 25 attempted suicides occur per every suicide death (Centers for Disease Control and Prevention, 2009). At present, the only way to recognize this kind of prior intention is based on an overall clinical evaluation based on previous attempted suicides, suicidal ideation, and psychopathology.

As recently reported by Nock et al. (2010), the attitude IAT may be useful in detecting suicidal ideations in people who attempted suicide. The author reported that implicit association between self and death in suicide attempters leads to a "…6-fold increase in the odds of making a suicide attempt in the next 6 months." The aIAT differs from IAT in that rather than measuring attitudes, it measures memories or, as shown here, prior intentions. Therefore, the aIAT can be useful for recognizing precocious signs of suicidal deliberations. Given that suicidal attitudes may fertilize suicidal deliberation, but they do not correspond to it, the aIAT may be a promising complementary procedure for predicting suicide.

Nonclinical applications of the aIAT might include its possible use within the forensic and investigative fields. Criminal law is all about the evaluation of a criminal intent, the so-called *mens rea*, and a criminal trial is based on the assumption that you may infer a defendant's intention by his acts or words. Science-based assessment of intent is allowed when the assessment of mental insanity is requested. In such circumstances, the burden of proof is to show that "free will" is overwritten by a mental illness. In this view, the criminal act is the result of such mental illness and the crime is a symptom of it. In such cases, mental illness has to be blamed, rather than the defendant. Consider the hypothetical case of a defendant claiming to have killed under the direct order of the devil; available techniques for validating this verbal report rely solely on self-report, which may be intentionally distorted in order to obtain legal advantages. The aIAT could be used to directly test whether the intention to kill was triggered by the defendant's mind passively obeying the devil's order or whether the devil's words had no triggering role and were just made up for the defendant to be cleared. However, this particular application is still a few steps away. Here, we have shown that we can detect intent before action, but forensic applications today typically require proving the existence of an intent preceding a crime which happened some time ago; this is a crucial step for evaluating the defendant's mind at the time of the crime.

Reprint requests should be sent to Prof. Giuseppe Sartori, Dipartimento di Psicologia Generale, Via Venezia 8, 35131, Padova, Italy, or via e-mail: sara.agosta@iit.it.

REFERENCES

Ajzen, I., & Madden, T. J. (1986). Prediction of goal-directed behavior: Attitudes, intentions, and perceived behavioral control. *Journal of Experimental Social Psychology, 22,* 453–474.

Audi, R. (1973). Intending. *Journal of Philosophy, 70,* 387–403.

Becchio, C., Sartori, L., Bulgheroni, M., & Castiello, U. (2008a). Both your intention and mine are reflected in the kinematics of my reach-to-grasp movement. *Cognition, 106,* 894–912.

Becchio, C., Sartori, L., Bulgheroni, M., & Castiello, U. (2008b). The case of Dr. Jekyll and Mr. Hyde: A kinematic study on social intention. *Consciousness and Cognition, 17,* 557–564.

Beck, A. T., Kovacs, M., & Weissman, A. (1979). Assessment of suicidal intention: The Scale for Suicide Ideation. *Journal of Consulting and Clinical Psychology, 47,* 343–352.

Berkum, J. J. A., Hagoort, P., & Brown, C. M. (1999). Semantic integration in sentences and discourse: Evidence from the N400. *Journal of Cognitive Neuroscience, 11,* 657–671.

Bratman, M. E. (1987). *Intentions, plans and practical reason*. Cambridge, MA: Harvard University Press.

Centers for Disease Control and Prevention (2009). Violence Prevention. Suicide Prevention. Retrieved from: www.cdc.gov/ViolencePrevention/suicide/index.html, May 19, 2011.

Cohen, P. R., & Levesque, H. J. (1990). Intention is choice with commitment. *Artificial Intelligence, 42,* 213–261.

Doucet, C., & Stelmack, R. M. (1999). The effect of response execution on P3 latency, reaction time, and movement time. *Psychophysiology, 36,* 351–363.

Einstein, G. O., McDaniel, M. A., Richardson, S. L., Guynn, M. J., & Cunfer, A. R. (1995). Aging and prospective memory: Examining the influences of self-initiated retrieval processes. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 21,* 996–1007.

Einstein, G. O., McDaniel, M. A., Williford, C. L., Pagan, J. L., & Dismukes, R. K. (2003). Forgetting of intentions in demanding situations is rapid. *Journal of Experimental Psychology: Applied, 9,* 147–162.

Ellis, J. A. (1996). Perspective memory or the realization of delayed intentions: A conceptual framework for research. In M. Brandimonte, G. O. Einstein, & M. A. McDaniel (Eds.), *Prospective memory: Theory and applications* (pp. 1–22). Mahwah, NJ: Erlbaum.

Fishbein, M., & Ajzen, I. (1975). *Belief, attitude, intention, and behavior: An introduction to theory and research*. Reading, MA: Addison-Wesley.

Gollwitzer, P. M. (1993). Goal achievement: The role of intentions. *European Review of Social Psychology, 4,* 141–185.

Gollwitzer, P. M. (1999). Implementation intentions: Strong effects of simple plans. *American Psychologist, 54,* 493–503.

Greenwald, A. G., McGhee, D. E., & Schwartz, J. L. K. (1998). Measuring individual differences in implicit cognition: The Implicit Association Test. *Journal of Personality and Social Psychology, 74,* 1464–1480.

Greenwald, A. G., Nosek, B. A., & Banaji, M. R. (2003). Understanding and using the Implicit Association Test: An improved scoring algorithm. *Journal of Personality and Social Psychology, 85,* 197–216.

Haggard, P. (2005). Conscious intentions and motor cognition. *Trends in Cognitive Sciences, 9,* 290–295.

Haggard, P., & Eimer, M. (1999). On the relation between brain potentials and the awareness of voluntary movements. *Experimental Brain Research, 1,* 128–133.

Hagoort, P., Hald, L., Bastiaansen, M., & Petersson, K. M. (2004). Integration of word meaning and world knowledge in language comprehension. *Science, 304,* 438–441.

Haynes, J. D., Sakai, K., Rees, G., Gilbert, S., Frith, C., & Passingham, R. (2007). Reading hidden intentions in the human brain. *Current Biology, 17,* 1–6.

Israel, J. B., Chesney, G. L., Wickens, C. D., & Donchin, F. (1980). P300 and tracking difficulty: Evidence for multiple resources in dual performance. *Psychophysiology, 17,* 57–70.

Israel, J. B., Wickens, C. D., Chesney, G. L., & Donchin, E. (1980). The event-related brain potential as an index of display monitoring workload. *Human Factors, 22,* 211–224.

Johnson, R., Jr., Barnhardt, J., & Zhu, J. (2003). The deceptive response: Effects of response conflict and strategic monitoring on the Late Positive Component and episodic memory-related brain activity. *Biological Psychology, 64,* 217–253.

Johnson, R., Jr., Henkell, H., Simon, E., & Zhu, J. (2008). The self in conflict: The role of the executive processes during truthful & deceptive responses about attitudes. *Neuroimage, 39,* 469–482.

Kramer, A. F., Wickens, C. D., & Donchin, E. (1985). Processing of stimulus properties: Evidence for dual-task integrality. *Journal of Experimental Psychology: Human Perception and Performance, 11,* 393–408.

Kutas, M., & Federmeier, K. D. (2000). Electrophysiology reveals semantic memory use in language comprehension. *Trends in Cognitive Sciences, 4,* 463–470.

Kutas, M., & Hillyard, S. A. (1980). Reading senseless sentences: Brain potentials reflect semantic incongruity. *Science, 207,* 203–205.

Lau, H. C., Rogers, R. D., Haggard, P., & Passingham, R. E. (2004). Attention to intention. *Science, 303,* 1208–1210.

Libet, B., Gleason, C. A., Wright, E. W., & Pearl, D. K. (1983). Time of conscious intention to act in relation to onset of cerebral activity (readiness-potential). The unconscious initiation of a freely voluntary act. *Brain, 106,* 623–642.

Magliero, A., Bashore, T. R., Coles, M. G. H., & Donchin, E. (1984). On the dependence of P300 latency on stimulus evaluation processes. *Psychophysiology, 21,* 171–186.

McDaniel, M. A., Einstein, G. O., Graham, T., & Rall, E. (2004). Delaying execution of intentions: Overcoming the costs of interruptions. *Applied Cognitive Psychology, 18,* 533–547.

Nock, M. K., Park, J. M., Finn, C. T., Deliberto, T. L., Dour, H. J., & Banaji, M. R. (2010). Measuring the suicidal mind: Implicit cognition predicts suicidal behaviour. *Psychological Science, 21,* 511–517.

Pacherie, E. (2008). The phenomenology of action: A conceptual framework. *Cognition, 107,* 179–217.

Pacherie, E., & Haggard, P. (2010). What are intentions? In L. Nadel & W. Sinnott-Armstrong (Eds.), *Benjamin Libet and Agency* (pp. 70–84). Oxford, UK: Oxford University Press.

Picton, T. W., Bentin, S., Berg, P., Donchin, E., Hillard, S. A., Johnson, R., et al. (2000). Guidelines for using human event-related potentials to study cognition: Recording standards and publication criteria. *Psychophysiology, 37,* 127–152.

Qu, C., Wang, J., & Luo, Y. (2008). Inconspicuous anchoring effects generated by false information. *Progress in Natural Science, 18,* 1375–1382.

Sartori, G., Agosta, S., & Gnoato, F. (2007). *High accuracy detection of malingered whiplash syndrome*. Paper presented at the International Whiplash Trauma Congress, Miami, FL.

Sartori, G., Agosta, S., Zogmaister, C., Ferrara, S. D., & Castiello, U. (2008). How to accurately assess autobiographical events. *Psychological Science, 18,* 772–780.

Sartori, G., Polezzi, D., Mameli, F., & Lombardi, L. (2005). Feature type effects in semantic memory: An event related potentials study. *Neuroscience Letters, 390,* 139–144.

Sartori, L., Becchio, C., Bulgheroni, M., & Castiello, U. (2009). Modulation of the action control system by social intention: Unexpected social requests override preplanned action. *Journal of Experimental Psychology, 35,* 1490–1500.

Searle, J. R. (1983). *Intentionality, an essay in the philosophy of mind*. Cambridge, UK: Press Syndicate of the University of Cambridge.

Smith, M. E., & Halgren, E. (1987). Event-related potentials during lexical decision: Effects of repetition, word frequency, pronounceability, and concreteness. *Electroencephalography and Clinical Neurophysiology, 40,* 417–421.

Soon, C. S., Brass, M., Heinze, H. J., & Haynes, J. D. (2008). Unconscious determinants of free decisions in the human brain. *Nature Neuroscience, 11,* 543–545.

Van Petten, C., & Kutas, M. (1991). Influences of semantic and syntactic context on open and closed class words. *Memory & Cognition, 19,* 95–112.

Wickens, C. D., Kramer, A., Vanasse, L., & Donchin, F. (1983). The performance of concurrent tasks: A psychophysiological analysis of the reciprocity of information processing resources. *Science, 221,* 1080–1082.