Temporal dynamics of cognitive-emotional interplay in moral decision-making.

Sarlo, Michela; Lotto, Lorella; Manfrinati, Andrea; Rumiati, Rino; Gallicchio, Germano; Palomba, Daniela

Journal of Cognitive Neuroscience

DOI:
https://doi.org/10.1162/jocn_a_00146

Published: 01/04/2012

Temporal Dynamics of Cognitive–Emotional Interplay in Moral Decision-making

Michela Sarlo, Lorella Lotto, Andrea Manfrinati, Rino Rumiati, Germano Gallicchio, and Daniela Palomba

Abstract

■ This study investigated the temporal dynamics of emotional and cognitive processing underlying decision-making in moral judgment. Thirty-seven participants were presented with a set of 60 dilemmas varying in whether killing one individual was an intended means to save others (instrumental dilemmas) or a foreseen but unintended consequence (incidental dilemmas). Participants were required to decide between Options A (letting a specific number of people die) and B (killing one person to save a specific number of people). ERPs were recorded to a slide displaying the letters A and B while subjects were deciding between the options, and movement-related potentials were recorded time-locked to the behavioral response, thus allowing the investigation of both stimulus- and response-related processes during decision-making. Ratings of emotional valence and arousal experienced during decision-making were collected after each decision. Compared with incidental dilemmas, instrumental dilemmas prompted a lower number of B choices and significantly more unpleasant decisions. A larger P260 component was found in the frontopolar and frontal areas when subjects were deciding on instrumental than incidental dilemmas, possibly reflecting an immediate affective reaction during the early stage of assessment and formation of preferences between available options. On the other hand, decisions on incidental dilemmas required greater attentional resources during the fairly controlled later processing, as reflected in the larger slow wave amplitudes. In addition, facilitation of action selection and implementation was found for incidental dilemmas during the second stage of decision-making, as supported by the larger amplitudes of both components of the Bereitschaftspotential. ■

INTRODUCTION

Recent research has begun to focus increasingly on the role of emotional processes in moral judgment, using different theoretical and methodological approaches. Although it appears clear that emotions do influence moral cognition (Haidt, 2001, 2003; Pizarro, 2000; Damasio, 1994), the complex interplay between affective and cognitive processing during moral decision-making is far from being understood (cf. Huebner, Dwyer, & Hauser, 2009).

On this perspective, a large body of philosophical and empirical work has been devoted to determining the specific factors that affect people's resolutions of moral dilemmas. Generally, a moral dilemma involves a conflict in choosing between two undesirable alternatives, both of which have aversive consequences and none of which clearly emerge as the right choice (Braunack-Mayer, 2001; Sinnott-Armstrong, 1987), such as in choosing between killing one person and letting many people die. Whatever the choice is, either the moral obligation of not killing or the moral requirement of helping others is inevitably violated. The trolley and the footbridge problems (Thomson, 1985; Foot, 1967) are prototypical examples of this condition. In the trolley dilemma, the only way to save five workers from a runaway trolley is to pull a lever redirecting the trolley onto a sidetrack, where it will kill a single worker. In the footbridge dilemma, the only way to save the five workers is to push a large man off an overpass onto the track, where he will die while his body will stop the trolley. Despite the identical outcomes of the proposed actions (i.e., causing the death of one person and saving five people), moral judgments in the two dilemmas appear to be driven by different principles, as most people judge that pulling the lever in the trolley dilemma is morally acceptable, whereas pushing the man in the footbridge dilemma is not (Hauser, Cushman, Young, Jin, & Mikhail, 2007; Koenigs et al., 2007; Greene, Sommerville, Nystrom, Darley, & Cohen, 2001; Thomson, 1985).

According to the dual-process theory (Greene, Morelli, Lowenberg, Nystrom, & Cohen, 2008; Greene, Nystrom, Engell, Darley, & Cohen, 2004; Greene et al., 2001), emotion is the critical factor differentially affecting moral judgment in the two types of dilemmas. In the case of the footbridge problem, a "personal" moral violation would evoke a strong negative emotional response that would prevail over rational reasoning, thus determining moral disapproval. On the other hand, in the trolley problem the "impersonal" nature of the moral violation would elicit a weaker emotional response, thus allowing cognitive control to drive rational utilitarian computations (i.e.,

University of Padova

maximizing benefits and minimizing costs). In their earlier works, Greene and colleagues (2001, 2004) classified moral dilemmas as personal if the proposed action caused (a) serious bodily harm (b) to a specific person or group of people and (c) not by deflecting an existing threat. Moral impersonal dilemmas simply would not meet these three criteria. Initially rooted in the personal–impersonal distinction, but not limited to it (see Greene, 2009), the dual-process theory postulates that moral judgments are the product of two competing processing systems: a slow, controlled cognitive system, favoring utilitarian judgments, and a fast, automatic emotional system, driving nonutilitarian judgments. Converging evidence from neuroimaging and lesion studies provides support for this proposal, suggesting the engagement of relatively dissociable neural systems in moral judgment.

In a series of fMRI studies (Greene et al., 2001, 2004), personal moral dilemmas elicited greater activation in brain areas commonly associated with emotions (including medial frontal gyrus, posterior cingulate gyrus, and STS), whereas impersonal moral dilemmas elicited greater activation in areas associated with problem solving and working memory (including dorsolateral pFC and inferior parietal lobule). Moreover, utilitarian judgments in "high-conflict" personal dilemmas (i.e., in which people's judgments tended to disagree and response times were slower) were found to be associated with greater activation of the dorsolateral pFC relative to nonutilitarian judgments (Greene et al., 2004), suggesting that increased engagement of brain areas involved in executive functions is necessary to override the immediate aversive emotional response. In other words, greater cognitive control is required to resolve a conflict between spontaneous aversion toward causing direct harm and rational cost–benefit computation (Greene, 2009; Greene et al., 2004).

Further support for the dual-process theory is provided by recent neuropsychological studies. As compared with healthy controls, patients with frontotemporal dementia (Mendez, Anderson, & Shapira, 2005) and with focal lesions to the ventromedial prefrontal areas (Ciaramelli, Muccioli, Ladavas, & di Pellegrino, 2007; Koenigs et al., 2007) showed a higher proportion of utilitarian judgments in personal dilemmas, whereas no differences between patients and controls emerged in judging impersonal moral violations. Importantly, by applying anodal transcranial direct current stimulation (i.e., simulating a lesion) over the ventral pFC in healthy volunteers during a moral judgment task, Fumagalli and colleagues (2010) found an increase in the number of utilitarian choices in female subjects, who generally show a greater propensity to altruistic behavior. Taken together, these findings are consistent with the idea that emotional processing depending on the integrity of the ventromedial pFC is crucial for nonutilitarian resolutions of moral dilemmas (Cushman, Young, & Greene, 2010).

Although the pioneer fMRI studies by Greene and colleagues (2001, 2004) generated a large interest for the neural bases of moral judgment, several criticisms have been raised against the personal–impersonal distinction (e.g., McGuire, Langdon, Coltheart, & Mackenzie, 2009; Hauser et al., 2007). Indeed, as recently acknowledged by Greene (2009), other features of the footbridge and trolley dilemmas might produce the obtained pattern of judgments. In particular, a number of studies have focused on the role played by the intentionality of action, as this principle has large application in medical ethics and legal decisions (Boyle, 2004; Gillon, 1999). The intention principle refers to the doctrine of the double effect (DDE; Aquinas, 1265–1272/1947; see also Foot, 1967), according to which, it is morally unacceptable to kill one individual as an intended means for a greater good, although it is acceptable as a foreseen but unintended consequence. When using a set of dilemmas developed specifically to probe the DDE, intentional harm was found to be judged less morally appropriate than unintentional harm (Moore, Clark, & Kane, 2008; Hauser et al., 2007; Borg, Hynes, Van Horn, Grafton, & Sinnott-Armstrong, 2006; Cushman, Young, & Hauser, 2006). Furthermore, greater fMRI activation was observed in areas associated with emotional processing (i.e., STS and OFC) during the resolution of moral dilemmas involving intentional than dilemmas involving unintentional harm, with the latter eliciting greater activation in the cognitive areas (including the superior occipital gyrus, the angular gyrus, and the SMA; Borg et al., 2006). Therefore, the DDE does play a role in guiding moral judgments, and most importantly, this role appears to be mediated by emotional processes.

By using ERPs, this study aimed at investigating the cognitive–emotional interplay in moral judgment with a set of dilemmas inspired by the DDE. One of the most intriguing issues is indeed the temporal dynamics of emotional processing involved in moral judgment. Given the low temporal resolution of fMRI, it remains critically important to determine the time at which emotion affects moral decision-making, as significant information on its possible causal role would be provided (cf. Huebner et al., 2009). ERPs do provide the temporal resolution needed to assess in real time the neural activation underlying decision-making. To our knowledge, there is only one published ERP study investigating the neural correlates of moral judgment (Chen, Qiu, Li, & Zhang, 2009). By using dilemmas in which participants had to decide who to rescue from an earthquake, one of two relatives and one of two strangers, the authors found that a larger P2 was elicited when choosing between two relatives than between two strangers, indicating conflict detection during early stimulus evaluation. Furthermore, a greater positivity between 350 and 450 msec poststimulus was found to the pairs of relatives than to the pairs of strangers only after hearing a false aftershock warning, suggesting that emotional information modulated conflict resolution processes. However, this kind of experimental situation greatly differs from the classic moral dilemmas employed in the aforementioned fMRI studies, as no utilitarian resolution was truly available and no real choice between alternative hypothetical actions was given. It is, therefore, possible that the patterns of neural activation obtained by Chen and colleagues (2009) simply reflected differences in choosing between familiar, emotionally salient names and unfamiliar, unemotional names.

In this study, several novel features were introduced to investigate the time course of neural processes associated with decision-making in the context of moral dilemmas. It is acknowledged that moral cognition involves multiple cognitive processes and cortical networks (e.g., Moll, Zahn, de Oliveira-Souza, Krueger, & Grafman, 2005) and that decision-making per se implies a complex set of processes involving a distributed network of brain areas (Ernst & Paulus, 2005). However, within this limitation, it is still possible to highlight two temporally and functionally distinct phases consisting of (a) the appraisal of available options and the formation of preferences and (b) the selection, implementation, and execution of an action according to previous evaluations. These phases can engage in various degrees of both cognitive and affective processes, which, in turn, can involve both automatic and conscious modalities of processing (Ernst & Paulus, 2005; Paulus, 2005).

We designed a task in which participants were required to read a scenario followed by two alternative hypothetical resolutions and then make a decision during the presentation of a stimulus array ("decision slide") that was the same across conditions. By measuring cortical potentials time-locked to the decision slide and to the behavioral response, we were able to explore the temporal dynamics of neural activation in two distinct phases of decision-making: one in which the resolutions and their consequences were assessed and compared and one in which the corresponding action was selected and executed. Finally, to clarify the role played by emotional processes in guiding moral judgment, affective valence and arousal experienced during decision-making were collected after each decision.

We hypothesized that, during the resolution of moral dilemmas involving intentional harm, emotional processes would be more strongly engaged. A critical question was whether emotional engagement would be reflected in the early or late ERP components, thus affecting more automatic versus controlled processing stages. Although unable to capture completely the cognitive–emotional processing of moral dilemmas, which presumably begins when reading the scenario and the options, our paradigm can shed light on some specific phases of decision-making and on the emotional mechanisms underlying moral judgment.

METHODS

Participants

Thirty-seven healthy undergraduates (18 men) were recruited at the University of Padova. Participants were aged 19–28 years ($M = 23.7$, $SD = 1.9$), were right-handed, had no history of psychiatric or neurological disorders, and had normal or corrected-to-normal vision. They were paid €13 for their participation. The study was approved by the local ethics committee, and all volunteers gave written consent before participation.

Stimulus Material

We developed 60 experimental and 12 filler moral dilemmas, some of which were adapted from Greene et al. (2001, 2008) and Cushman et al. (2006). On the basis of the DDE (Aquinas, 1265–1272/1947), the 60 experimental dilemmas were classified into 30 "instrumental" dilemmas, which described killing one individual as an intended means to save others, and 30 "incidental" dilemmas, which described killing one individual as a foreseen but unintended consequence of saving others.[1] Instrumental and incidental dilemmas were carefully matched for numerical consequences (i.e., the number of people to save or let die) and self-involvement (i.e., to save or let oneself die besides other people). Such features were varied across dilemmas to avoid automaticity in responding to conceptually similar issues. For similar reasons, 12 additional moral dilemmas were introduced as filler stimuli. They were structured similarly to experimental dilemmas but involved no deaths and described other moral issues, such as stealing, lying, and being dishonest. The filler condition was not analyzed and will not be discussed further here.

Each dilemma was presented as text, in white type (font, Arial; size, 20) against a gray background, through a series of three screens. The first one described the scenario, in which some kind of threat is going to cause the death of a group of persons; the second one described a hypothetical action in which the main character lets these people die (Option A); and the third one described an alternative hypothetical action in which the main character kills one individual to save these people (Option B). Participants had to choose between the two options. B choices were considered to be utilitarian, as they maximize overall utility (i.e., saving more lives), whereas A choices were considered to be nonutilitarian.

Mean number of words and number of text characters were fully balanced between instrumental and incidental scenarios [$M_{\text{words}} = 59.13$ and 59.13, $t(58) = 0.00$, $p = 1.00$; $M_{\text{characters}} = 352.10$ and 352.57, $t(58) = -.09$, $p = .93$] and Options A [$M_{\text{words}} = 19.33$ and 19.13, $t(58) = .89$, $p = .38$; $M_{\text{characters}} = 115.17$ and 113.17, $t(58) = .98$, $p = .33$] and B [$M_{\text{words}} = 30.87$ and 30.87, $t(58) = 0.00$, $p = 1.00$; $M_{\text{characters}} = 172.77$ and 178.97, $t(58) = -1.52$, $p = .13$].

The complete list of the standardized stimulus materials is reported in Lotto, Manfrinati, and Sarlo (submitted; for examples, see Table 1).

All dilemmas were presented on a 19-in. computer screen at a viewing distance of 100 cm. Stimulus presentation was accomplished with E-prime software (Psychology Software Tools, Pittsburgh, PA).

Table 1. Sample Instrumental, Incidental, and Filler Dilemmas

Dilemma	*Scenario*	*Option A*	*Option B*
Instrumental (self-involvement; numerical consequences: 5)	You are the fourth member in a roped party of five climbers. The lead climber has just secured himself to a rock when the second climber starts slipping, thus dragging along you and the others. All of you fall for several meters and then stop, hanging on a precipice. The weight is too heavy and the rope will not hold up for much longer.	As you cannot grab the face of the rock, you let the rope break off, and allow yourself and the other four climbers to fall to your deaths.	To lighten the weight, you unhook the rope that ties yourself to the last climber. You know that he will fall into the precipice and die, but you will have saved yourself and the other two climbers in the process.
Incidental (no self-involvement; numerical consequences: 6)	You are the pilot of a military aircraft in mission over South East Asia. During the flight, you realize that a missile has accidentally been launched by another military aircraft. The missile is directed toward a small tourist plane carrying six persons. You note a military reconnaissance aircraft in the surroundings of the missile.	You let the accidentally launched missile hit the tourist plane, thus killing the six persons on board.	You start the emergency missile destruction procedure. You know that the explosion will make the military reconnaissance aircraft precipitate and the pilot die, but the six persons on the tourist plane will be safe.
Filler	Because of the last year's economic crisis, the company in which you worked became bankrupt, and you lost your job. Lately, you have been looking for a new job, but unsuccessfully. You've realized you lack competence in computer skills, and you believe you would be hired more easily if you had a CV with such characteristics.	You include in your CV some false information about competence in computer skills. You will overcome other candidates who are more skilled than you are and will be hired.	You do not modify your CV. You know that candidates more skilled than you will overcome you in the ranking and will get the job you are applying for.

Texts are translated from Italian.

Procedure

Upon arrival, participants were given information about the experiment, and their written informed consent was obtained. They were then seated in a dimly lit, sound-attenuated room, and an elastic cap embedded with electrodes was applied for EEG recording. Following a 10-min adaptation period, instructions for the task were given.

Each trial began with the presentation of the scenario, which participants could read at their own pace. When the participant pressed the spacebar, Option A was presented for 4.5 sec. Next, Option B was presented for 6.5 sec.[2] After the offset of Option B, a fixation cross appeared in the middle of the screen between the letters A and B defining the respective options ("decision slide"). The two letters were presented vertically aligned at the center of a gray background. Participants were instructed to decide between the two hypothetical actions by pressing one of two computer keys marked A or B. They were explicitly told to wait for the decision slide before evaluating the two options. To avoid movement artifacts, participants were instructed to keep their index and middle fingers of the right hand above the keys throughout the task. After their response, participants were required to rate how they felt while they were deciding using a computerized version of the self-assessment manikin (Lang, Bradley, & Cuthbert, 2008), displaying the 9-point scales of valence (pleasantness/unpleasantness) and arousal (activation/calm), with higher scores indicating higher pleasantness and higher emotional arousal. Then, an intertrial interval of 1 sec elapsed before the next scenario was presented (see Figure 1 for a schematization of the procedure). Dilemmas were presented in three blocks of 24 trials each (10 instrumental, 10 incidental, and 4 filler dilemmas) and in random order within each block. Participants were allowed to take a short break at the end of each block. Two practice dilemmas were presented before the beginning of the experimental session.

Electrophysiological Recordings and Data Analyses

The EEG was recorded using an Electro-Cap with tin electrodes (Electrocap, Inc., Eaton, OH) from 31 scalp positions (Fpz, Fz, FCz, Cz, CPz, Pz, Oz, Fp1, Fp2, F3, F4, FC3, FC4, C3, C4, CP3, CP4, P3, P4, O1, O2, F7, F8, FT7, FT8, T3, T4, TP7, TP8, T5, and T6) and the right mastoid. All sites were referenced on-line to the left mastoid and digitally rereferenced off-line to the algebraic average of the left and right mastoids. For the purpose of artifact scoring, vertical and horizontal EOGs were recorded. Electrode pairs (bipolar) were placed at the supraorbit and suborbit of the right eye and at the external canthi of the eyes. All electrode impedances were kept below 10 kΩ. The EEG and EOG signals were amplified with Neuroscan Synamps (El Paso, TX), band-pass filtered (DC-70 Hz), digitized at 500 Hz (16-bit AD converter, accuracy of 0.1 μV per least significant bit), and stored on a Pentium II computer.

To compute ERPs, continuous EEG was segmented off-line into 900-msec epochs from 100 msec before to 800 msec after the onset of the decision slide. To compute movement-related potentials (MRPs), EEG was segmented off-line into 1500-msec epochs from 1000 msec before to 500 msec after the behavioral response (keypress). All epochs were linear detrended to correct for slow DC shifts and refiltered off-line with a low-pass filter set at 30 Hz (12 dB/oct, zero phase filter). EEG data were corrected for eye blinks and vertical and horizontal eye movements using a regression-based correction algorithm (eye movement correction procedure [EMCP]; Gratton, Coles, & Donchin, 1983). The EEG epochs were then baseline-corrected against the mean voltage during the 100-msec prestimulus period for ERP computation and during the 200-msec period (from −1000 to −800 msec) preceding the behavioral response for MRP computation. All epochs were visually scored for residual artifacts, and each portion of data containing artifacts greater than ±70 μV in any channel was rejected for all the recorded channels before further analysis. Artifact-free trials were separately averaged for each subject in each experimental condition. The average number of artifact-free trials entering analyses was 25.41 and 25.68 for incidental and instrumental dilemmas, respectively.

On the basis of visual inspection of grand-averaged ERP waveforms and condition effects, one prominent positive component peaking at about 260 msec was identified and specified as the most positive peak between 200 and 300 msec from stimulus onset (P260). Furthermore, because no clear peaks were discernible in the time interval after 300 msec, successive slow wave activity was measured as mean amplitude within three successive poststimulus time windows (300–450 msec, 450–600 msec, and 600–750 msec).

On the basis of the literature and visual inspection of grand-averaged MRP waveforms, the amplitudes of MRP components were measured in three time intervals: (1) mean negativity between 800 and 500 msec before keypress, referred to as early Bereitschaftspotential (BP); (2) mean negativity between 500 and 50 msec before keypress, referred to as late BP; and (3) mean negativity between 50 msec preceding and 100 msec following keypress, referred to as motor potential (MP).

Separate repeated measures ANOVAs were conducted on mean P260 amplitudes and peak latencies, mean slow wave amplitudes, and mean MRP amplitudes with Dilemma Type (instrumental and incidental), Electrode Location (Fp, F, FC, C, CP, P, and O), and Laterality (left, midline, and right) as within-subject factors. The Greenhouse–Geisser corrected p values for effects within variables with more than two levels are reported together with the uncorrected degrees of freedom. Significant main effects and interactions ($p < .05$) were followed by Newman–Keuls post hoc tests.

With regard to the behavioral and affective responses, the proportion of utilitarian choices was computed for each participant by dividing the number of B choices by the total number of response choices for each dilemma type ($n = 30$). Mean response times and mean valence and

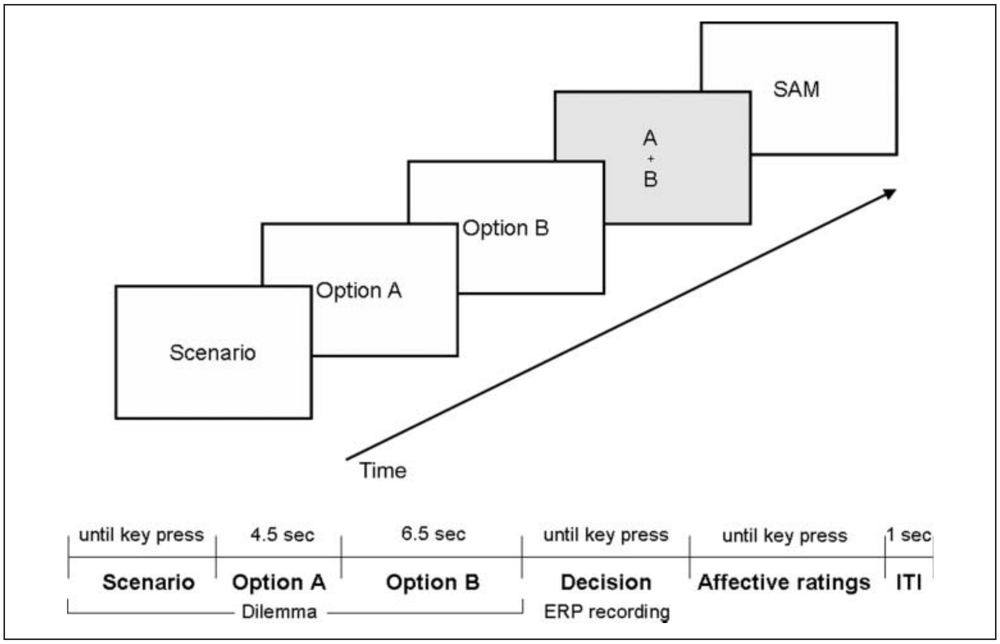

Figure 1. Sequence of events in the experiment. Participants had to decide between Options A and B by pressing the corresponding key during the presentation of the decision slide (in gray). ERPs were recorded time-locked to the decision slide onset. MRPs were recorded time-locked to the behavioral response. SAM = self-assessment manikin and ITI = intertrial interval. Text is not drawn to scale.

arousal ratings were also computed separately for each participant and dilemma type. Two-tailed t tests for paired samples were then performed to compare each dependent variable between conditions.

On the basis of Fumagalli et al.'s (2010) results, an ancillary analysis that tested for gender differences was performed by including the gender factor in the above analyses.

Lastly, Pearson's correlations were performed between electrophysiological measures and subjective and behavioral responses. By uncovering the degree of interrelationship between such variables, these analyses helped elucidate the functional significance of the ERP components obtained in this experimental context.

RESULTS

Behavioral Data

As expected, incidental dilemmas elicited a significantly higher proportion of utilitarian than nonutilitarian choices [$t(36) = 10.41, p < .00001$; Ms = .79 and .21, respectively], whereas the opposite holds for instrumental dilemmas [$t(36) = -3.05, p < .005$; Ms = .40 and .60, respectively]. Therefore, the proportion of utilitarian choices was largely lower for instrumental than incidental dilemmas [$t(36) = 15.88, p < .00001$].

No significant difference was found between the two types of dilemmas in response times [$t(36) = 0.52, p = .61$; Ms = 2505 and 2554 msec for instrumental and incidental dilemmas, respectively].

Affective Ratings

As for valence ratings, decisions for instrumental dilemmas were rated as significantly more unpleasant than for incidental dilemmas [$t(36) = 2.85, p < .008$; Ms = 2.13 and 2.32, respectively]. Both types of decisions were rated as highly unpleasant. No significant differences were found in arousal ratings between decisions for instrumental and incidental dilemmas (Ms = 5.89 and 5.92, respectively).

ERP Results

Grand-averaged ERPs elicited during decision-making as a function of instrumental and incidental dilemmas are displayed at representative midline sites in Figure 2.

P260

The significant Dilemma Type × Electrode Location [$F(6, 216) = 5.37, p < .007$] showed that the P260 amplitude was larger for instrumental than incidental dilemmas over the anterior sites (Figure 2). Post hoc comparisons revealed that this difference was significant at frontopolar (i.e., Fp1, Fpz, and Fp2; $p < .00003$) and frontal sites (i.e., F3, Fz, and F4; $p < .002$). No significant differences between dilemma types were found at other locations. Overall, the largest amplitudes were recorded at fronto-central, central, centro-parietal, and parietal sites [electrode location main effect: $F(6, 216) = 19.25, p < .00001$].

The analysis on P260 latency yielded only a significant Electrode Location × Laterality interaction [$F(12, 432) = 2.11, p < .04$], showing that P260 latency was progressively longer from frontopolar toward occipital sites, particularly at midline and on the left hemisphere.

Slow Waves (300–450, 450–600, and 600–750 msec Poststimulus)

The Dilemma Type × Electrode Location was found to be significant in the time window of 450–600 msec [$F(6, 216) = 4.27, p < .02$; Figure 2] and close to significance in the time windows of 300–450 msec [$F(6, 216) = 2.90, p < .07$] and 600–750 msec [$F(6, 216) = 2.55, p < .09$]. As specified by post hoc comparisons, greater positivity was observed for incidental than instrumental dilemmas at all sites except at frontopolar and frontal locations (ps < .03). Overall, the greatest positivity was recorded at parietal and occipital sites [Electrode Location main effect: $F(6, 216) = 38.41, p < .00001$; $F(6, 216) = 51.56, p < .00001$; and $F(6, 216) = 19.62, p < .00001$, respectively, in the three time windows].

MRP Results

Grand-averaged MRPs elicited during decision-making as a function of instrumental and incidental dilemmas are displayed at representative midline sites in Figure 3.

Early BP (from 800 to 500 msec before Response Onset)

The significant Dilemma Type × Electrode Location [$F(6, 216) = 4.54, p < .02$] reflected greater negativity for incidental than instrumental dilemmas at fronto-central, central, centro-parietal, and parietal sites, as specified by post hoc comparisons (all ps < .005). As supported by the Electrode Location × Laterality interaction [$F(12, 432) = 4.26, p < .002$], the largest amplitude of this component was observed at midline central and centro-parietal sites.

Late BP (from 500 to 50 msec before Response Onset)

As for the previous MRP component, a significant Dilemma Type × Electrode Location was found [$F(6, 216) = 4.67$,

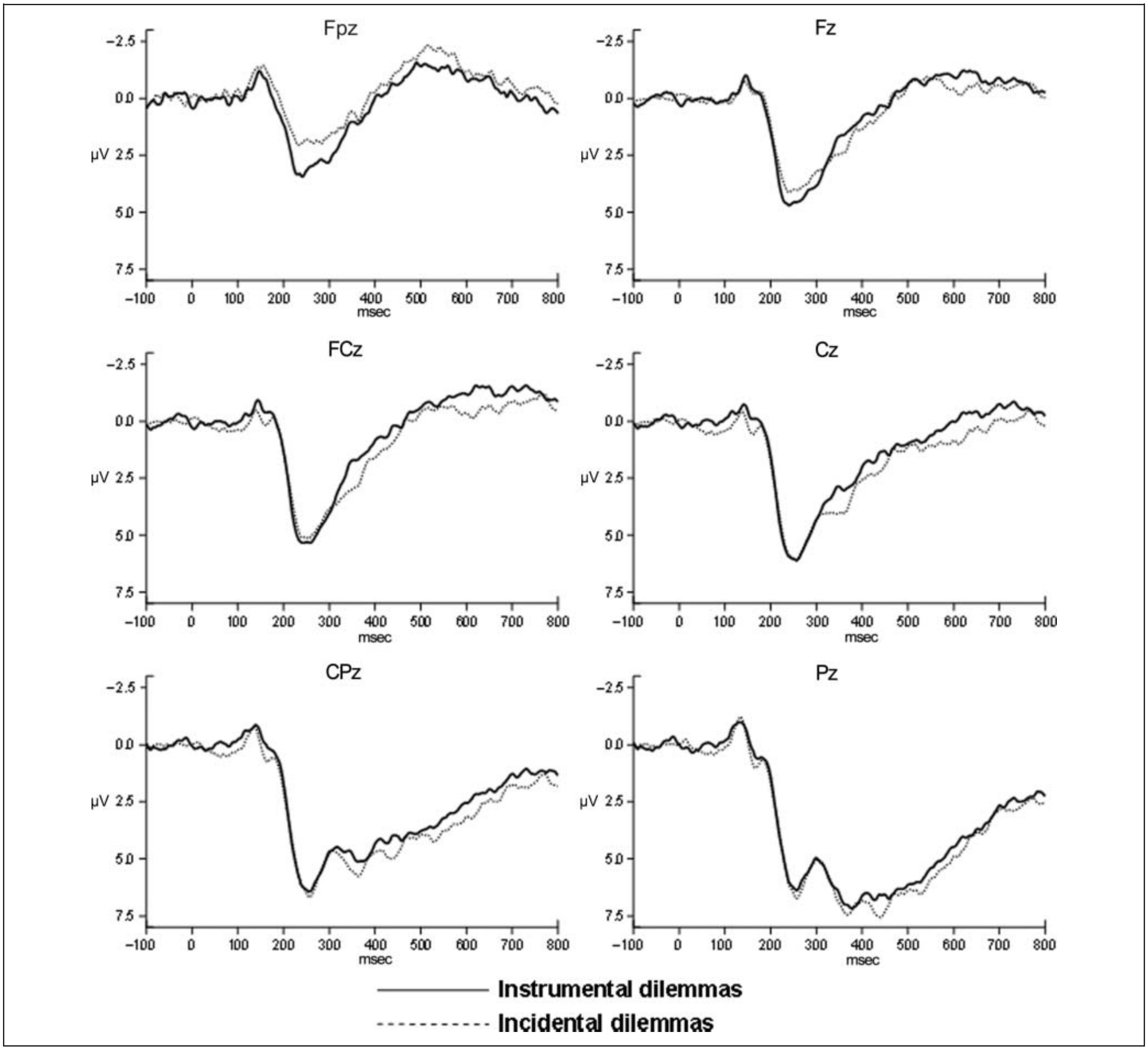

Figure 2. Grand-averaged ERPs recorded at representative midline sites time-locked to the decision slide for instrumental and incidental dilemmas. Time 0 indicates the onset of the decision slide.

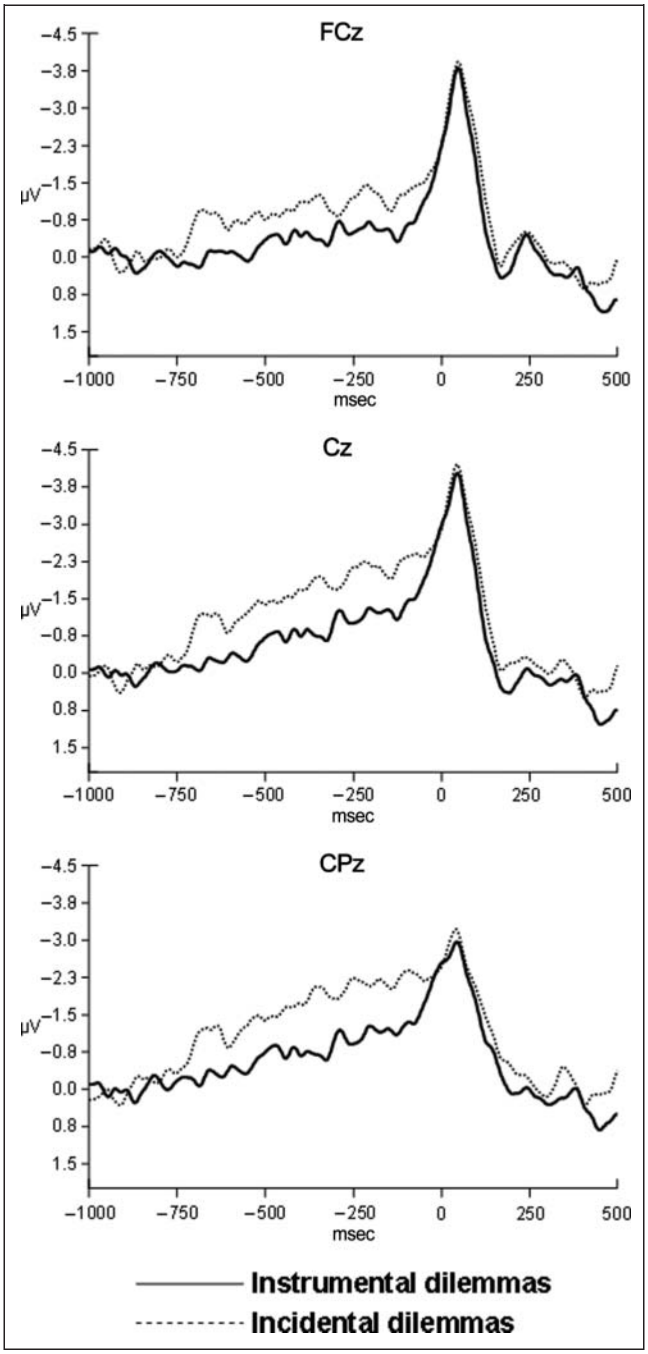

Figure 3. Grand-averaged MRPs recorded at representative midline sites time-locked to the behavioral response for instrumental and incidental dilemmas. Time 0 indicates the onset of the behavioral response.

$p < .02$], showing greater negativity for incidental than instrumental dilemmas at all locations except frontopolar and frontal sites, as supported by post hoc comparisons (ps $< .03$). The largest negativity was observed at midline and on the left hemisphere, at central and centro-parietal sites [Electrode Location × Laterality interaction: $F(12, 432) = 6.92$, $p < .00001$].

MP (from 50 msec before to 100 msec after Response Onset)

No significant effects of dilemma type were found for this MRP component. The largest negativity was observed at midline and on the left hemisphere, at central sites [Electrode Location × Laterality interaction: $F(12, 432) = 28.49$, $p < .00001$].

To summarize the electrophysiological results, topographical maps displaying significant ERP and MRP differences between incidental and instrumental conditions in their specific time windows are shown in Figure 4.

Correlational Analyses

Significant negative correlations were obtained between valence ratings and mean P260 amplitudes specifically over Fp1, Fpz, and Fp2 for instrumental dilemmas ($r = -.37$, $p < .03$; $r = -.36$, $p < .03$; and $r = -.35$, $p < .04$, respectively) and over Fp1 and Fp2 for incidental dilemmas ($r = -.40$, $p < .02$ and $r = -.33$, $p < .05$, respectively), indicating that the larger the P260 amplitudes over the frontopolar region, the higher the unpleasantness that was experienced during decision-making in both types of dilemmas. This effect was not seen for any other electrode. Although these correlations would not survive Bonferroni adjustment, which, however, does not take the spatial interdependence of EEG signals into

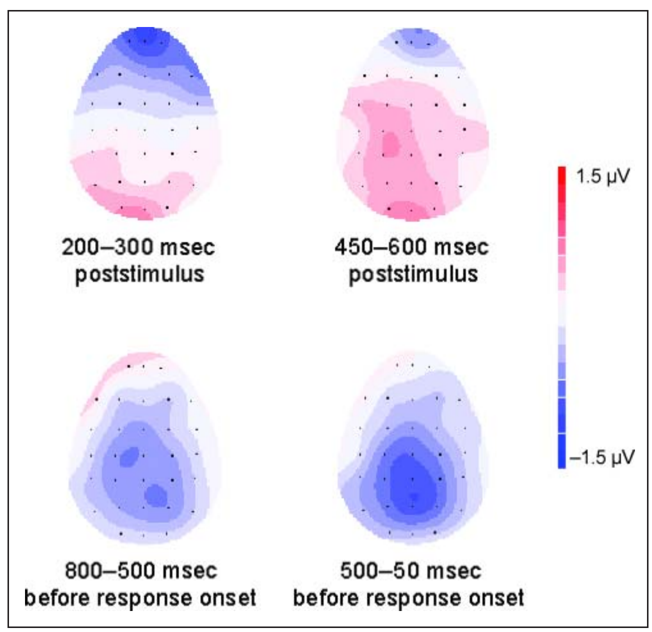

Figure 4. Topographical scalp distribution of the difference waves computed by subtracting the instrumental from the incidental condition in the time windows of 200–300 and 450–600 msec after stimulus onset (top) and in the time windows of 800–500 and 500–50 msec before response onset (bottom). Note that the greater anterior negativity displayed in the time window of 200–300 msec reflects, in fact, lower positivity for the incidental relative to the instrumental condition.

account (Skrandies, 1989), it is worth noting that an a priori hypothesis could be drawn by defining the frontopolar region (i.e., Fp1, Fpz, and Fp2) as an ROI, based on the effects found for the P260 amplitude.

Moreover, significant positive correlations were found between arousal ratings and mean slow wave amplitudes in the time window of 600–750 msec over more posterior locations for instrumental dilemmas only (EEG sites: FC3, FCz, FC4, C3, Cz, C4, CP3, CPz, CP4, P3, Pz, and P4; rs = .35–.55, ps = .03–.0001), indicating that the greater the cortical positivity, the higher the emotional arousal experienced during decision-making.

No significant correlations were observed between behavioral measures and either electrophysiological or self-report measures.

Analysis of Gender Differences

There were no significant main effects or interactions for gender either on the proportion of utilitarian choices or in response times (all Fs < .63, all ps > .42). With regard to the electrophysiological data, a significant Dilemma type × Gender interaction was obtained for the P260 amplitude [$F(1, 35) = 4.39, p < .05$] and for the slow wave amplitudes in the time windows of 450–600 msec [$F(1, 35) = 6.06, p < .02$] and 600–750 msec [$F(1, 35) = 4.50, p < .05$]. Such interactions show larger P260 amplitude differences between instrumental and incidental dilemmas in women than in men and larger slow wave amplitude differences in men than in women. However, post hoc tests revealed no significant comparisons for any of the obtained interactions. Lastly, no significant main effects or interactions were found for gender on the amplitudes of the relevant MRP components (all Fs < 2.3, all ps > .13). Therefore, gender differences will not be further discussed in the present article.

DISCUSSION

To the best of our knowledge, this is the first study using ERPs to assess the temporal dynamics of emotional and cognitive processing during decision-making in classic moral dilemmas. The time course of neural activation was recorded in response to a set of dilemmas varying in whether killing one individual was an intended means to save others (instrumental dilemmas) or a foreseen but unintended consequence (incidental dilemmas), according to the DDE (Aquinas, 1265–1272/1947).

In particular, a novel paradigm has been developed to overcome the drawbacks of fMRI studies in exploring different processing stages of moral cognition. Indeed, in the relevant fMRI literature (Borg et al., 2006; Greene et al., 2001, 2004), participants were allowed to read and respond to dilemmas at their own pace, while task-related hemodynamic activity was averaged across the whole reading and responding time window (Borg et al., 2006) or using a 16-sec floating window surrounding the time of response (Greene et al., 2001, 2004), as typically found in fMRI designs. As a result, processing associated with reading, encoding, decision-making, and response preparation could not be disentangled. In contrast, we employed a modified experimental paradigm that favored, for what is possible, the separation of the reading process from decision-making. Moreover, by separately investigating stimulus- and response-related processes, we were able to explore the neural correlates of two different phases of decision-making, involving the assessment of options and the selection of action, respectively (Ernst & Paulus, 2005; Paulus, 2005).

As expected, behavioral data showed that participants made a higher proportion of utilitarian judgments in response to incidental dilemmas and a higher proportion of nonutilitarian judgments in response to instrumental dilemmas. Accordingly, in line with what had been previously reported (Moore et al., 2008; Hauser et al., 2007; Borg et al., 2006; Cushman et al., 2006), instrumental dilemmas elicited a lower number of utilitarian choices than incidental dilemmas, indicating that it is less permissible to kill one individual as an intended means to save others than as a foreseen but unintended consequence of saving others. The moral principle of the double effect, according to which the experimental dilemmas were developed, was thus effective in determining participants' choices.

Another important novel feature of this study was the measurement of self-reported emotional experience at the time of judgment. To our knowledge, none of the studies on moral dilemmas reported above has directly examined participants' affective state during decision-making. Instead, emotion was inferred from the activation of brain areas commonly associated with emotional processing (Borg et al., 2006; Greene et al., 2001, 2004), by having an independent group of subjects rate each dilemma on the unoperationalized dimension of "emotional salience" (Koenigs et al., 2007), or by using an a priori criterion for considering some dilemmas as "putatively more emotional" than others (Greene et al., 2001, 2004). In this study, emotional experience was assessed along the independent dimensions of valence (pleasantness/unpleasantness) and arousal (activation/calm), as they represent the core affective components of emotion (e.g., Lang et al., 2008; Feldman Barrett & Fossum, 2001). Although acknowledging that a large proportion of emotional processes can occur unconsciously, we believe that exploring conscious emotional evaluation was a necessary, preliminary step toward understanding the emotional mechanisms underlying moral judgment. Results showed that, although both types of dilemmas elicited negative affect, decisions on instrumental dilemmas were significantly more unpleasant than those on incidental dilemmas. Interestingly, decisions on the two types of dilemmas were rated as equally arousing, indicating that the respective emotional states did differ on the degree of aversiveness rather than on the intensity of emotional activation, thus dissociating the two primary affective dimensions.

Critical information on the dynamic interplay between emotional and cognitive processing during different phases of decision-making was provided by the analysis of both stimulus- and response-locked cortical potentials.

In ERP waveforms time-locked to the onset of the decision slide, a prominent positive component was apparent for both types of dilemmas, peaking at about 260 msec. However, greater P260 amplitude was found when deciding on instrumental than incidental dilemmas over frontopolar and frontal locations. Crucially, a significant positive correlation between unpleasantness experienced during decision-making and P260 amplitude was obtained specifically over the frontopolar region, thus supporting the interpretation that this component reflects immediate affective reaction toward moral dilemmas during the first phase of decision-making. In particular, it might represent the aversive impact of having to choose between the two undesirable alternatives proposed by dilemmas. Such early emotional response was found to be significantly greater when subjects were deciding on instrumental than incidental dilemmas and might have eventually modulated moral judgments in favor of nonutilitarian resolutions. On the basis of the focal topographical distribution of these effects, we might speculate that the differences in frontopolar scalp activity were mediated by the activation of the OFC/ventromedial pFC, whose role in emotion-based decision-making is widely acknowledged (e.g., Damasio, 1994). Moreover, previous fMRI studies have consistently demonstrated medial prefrontal involvement during the resolution of "personal" (Greene et al., 2001, 2004) as well as "intentional" (Borg et al., 2006) moral dilemmas. These results also fit well with the observation that inhibiting the anterior pFC by applying cathodal transcranial direct current stimulation over the frontopolar region leads to an increase of deceptive behavior and to a decrease in feelings of guilt, thus reducing the moral conflict associated with lying (Karim et al., 2010).

The analysis of slow wave activity following P260 yielded further relevant information on the decision process during the fairly controlled later processing. Greater cortical positivity was found during decisions on incidental than instrumental dilemmas at more posterior locations, particularly in the time window of 450–600 msec. The amplitude of this late positive potential is assumed to be proportional to the allocation of attentional resources and working memory load (e.g., Rösler & Heil, 1991) or to the amount of processing and cognitive effort required for a decision (Ruchkin, Munson, & Sutton, 1982). Therefore, the greater amplitude found for incidental dilemmas is most likely to reflect additional effortful, controlled cognitive processing required for a cost–benefit computation that eventually favors utilitarian judgments, in line with the interpretations of previous fMRI research (Borg et al., 2006; Greene et al., 2001, 2004). Importantly, the lack of relationship between slow wave amplitudes and affective ratings for incidental dilemmas in any of the late time windows allowed us to suggest that information processing in this phase of decision-making was unrelated to conscious emotional activation. In contrast, for instrumental dilemmas, significant positive correlations were obtained between arousal ratings and slow wave amplitudes in the time window of 600–750 msec, suggesting that allocation of attentional resources was modulated by emotional intensity, as commonly reported for the processing of affective stimuli (e.g., Cuthbert, Schupp, Bradley, Birbaumer, & Lang, 2000). Taken together, these results support the idea that decisions on instrumental and incidental moral dilemmas not only require different amounts of attentional resources but also rely on functionally distinct processes, involving differential engagement of emotional and cognitive processing.

To explore the second phase of decision-making, during which the intention-based action is selected, initiated, and performed, response-locked MRPs were analyzed in three consecutive time windows, starting at 800 msec before the behavioral response. The BP is known to reflect an increase in cortical excitability of brain areas involved in the preparatory processes preceding the execution of voluntary movement (Shibasaki & Hallett, 2006). The early component (until about 500 msec before movement onset) is most likely to reflect the bilateral activation of the SMA, which plays a key role in the programming of internally generated movements and/or in the timing of movement initiation (Cunnington, Bradshaw, & Iansek, 1996). The late component (from 500 msec to movement onset) appears to reflect activity of the contralateral premotor and primary motor cortex and is influenced more by specific features of movement implementation. Results showed larger amplitudes of both the early and late components of the BP for incidental than instrumental dilemmas, indicating greater motor preparation and readiness to execute the action representing the selected option. This fits nicely with the fMRI finding that greater SMA activation was elicited by dilemmas involving unintentional than intentional harm (Borg et al., 2006), although this specific effect was not interpreted by the authors. Importantly, no difference between the two types of dilemmas emerged in the amplitudes of the MP, that is, the highest negativity developing right before movement onset, as this MRP component only reflects the ultimate transmission of the descending motor command from the primary motor cortex (Shibasaki & Hallett, 2006).

As a last remark, comparable response times were observed for instrumental and incidental dilemmas, despite the striking differences in stimulus- and response-related processes. In addition, no significant correlations were found between behavioral and electrophysiological measures. Therefore, it is possible that the differential contribution of emotional and cognitive processes to the two types of dilemmas eventually shaped response choices, rather than affecting the duration of the whole decision process, at least with a paradigm in which decision was measured independent of reading the dilemma description.

In summary, this study provided new insights into the role of emotional and cognitive processes in moral judgment, thus extending prior research on decision-making in moral dilemmas. As compared with incidental dilemmas, instrumental dilemmas elicited a stronger aversive response in the early phase of decision-making, as indexed by the larger P260 found at the most anterior locations. This neural event might represent an "alarm-bell emotion," signaling aversion to intentional harm and driving moral judgments toward nonutilitarian resolutions, as proposed by the dual-process theory (Greene et al., 2001, 2004, 2008). Furthermore, in the later processing stages, decisions on instrumental dilemmas required lower amounts of attentional resources, and information processing was strongly modulated by emotional arousal. Lastly, a lower cortical excitability characterized the final phase of decision-making preceding the motor response, possibly reflecting a higher conflict between alternative motor responses representing the different decision choices. In contrast, incidental dilemmas were found to elicit a weaker early aversive response and to require greater cognitive control in the later stages of processing, with no more evidence of emotional engagement. Such greater involvement of cognitive resources might reflect a cost–benefit computation that eventually favored utilitarian judgments, as hypothesized by the dual-process theory (Greene et al., 2001, 2004, 2008). Consistent with this view, the finding of a greater cortical negativity during motor preparation strongly suggests facilitation of action selection and implementation in dilemmas involving unintentional harm.

Some limitations of this study are worth mentioning. First, constraints to the experimental design have been imposed by the ERP technique. The need to measure the neural responses to discrete stimuli made it impossible to analyze the cortical activity associated with each option, because the EEG signal would have been contaminated by eye movements during reading and because reading itself is a dynamic process. Therefore, we tried to postpone the decision process as much as possible until the onset of a discrete stimulus (i.e., the decision slide). This was pursued by giving participants specific instructions, by employing fixed presentation times for each option, and by leaving as second the option describing the action to be performed (so that participants presumably had to complete its reading before assessing and comparing the two options). However, we do acknowledge that the options were an integral part of each dilemma, thus involving attentional demand, working memory load, and emotional processing that might have interacted with, and contributed to, the cognitive–emotional processes we intended to assess during decision-making. We also acknowledge that decision-making involves a set of complex and dynamic overlapping processes, thus making it challenging to isolate its phases. However, we believe that our paradigm, despite its limitations, was able to shed light on some specific phases of decision-making, providing relevant temporal information to the dual-process model of moral judgment.

Reprint requests should be sent to Michela Sarlo, Department of General Psychology, Via Venezia 8, 35131 Padova, Italy, or via e-mail: michela.sarlo@unipd.it.

Notes

1. The instrumental–incidental distinction may give the impression to overlap with Greene et al.'s (2001, 2004) personal–impersonal distinction, particularly when considering some specific dilemmas such as the trolley and the footbridge. However, the two distinctions are different for at least two reasons. First, the instrumental–incidental distinction is based on a single traditional philosophical principle, namely, the DDE (Aquinas, 1265–1272/1947), which holds that an action that has both good and bad effects may be morally permissible if (a) the action is not bad per se, (b) the intended final end is good, (c) the bad effects are foreseen but not directly intended, and (d) the good effects are proportionate to the bad effects. On this basis, in all the incidental dilemmas, the harmful act complies with the DDE, whereas in all the instrumental dilemmas, the harmful act violates the DDE to achieve a greater good. In contrast, the personal–impersonal distinction does not reflect any specific philosophical principle, not even the DDE, as in some of the impersonal dilemmas, the proposed action violates the DDE (see, as an example, the "sculpture," "speedboat," and "resume" dilemmas; Greene et al., 2001), and in some of the personal dilemmas, the proposed action seems more self-interested rather than being performed in the interest of a greater good (see, as an example, the "country road," "hired rapist," and "smother for dollars" dilemmas; Greene et al., 2001). A second, related reason is that Greene et al.'s (2001, 2004) three criteria are meant to define only the personal dilemmas. The impersonal dilemmas remain largely undefined (as they simply do not have to meet at least one of the three criteria), thus including a wide range of different moral issues. In contrast, both instrumental and incidental dilemmas are defined through the intentional structure of the proposed actions, as formally stated in the DDE. A last, methodological consideration highlights a further difference between the two distinctions: in both instrumental and incidental dilemmas, the proposed actions involve the death of people, so that our dilemmas do not differ for such an important variable that, per se, might engage emotions. In contrast, many of the proposed actions in impersonal dilemmas do not involve death or serious bodily harm, whereas all the proposed actions in personal dilemmas do. To summarize, whereas the instrumental–incidental distinction is strictly based on the intentionality of the proposed actions (consistent with the DDE), Greene et al.'s personal–impersonal distinction is based on broader criteria that the authors themselves admit to be only a provisional attempt to capture the relevant features that engage emotions in the footbridge-like versus trolley-like dilemmas. In the light of these considerations, we therefore believe that the instrumental–incidental distinction, which has previously been tested in other studies, although labeled differently (Moore et al., 2008; Hauser et al., 2007; Borg et al., 2006; Cushman et al., 2006), would allow a more controlled evaluation of the emotional and cognitive processes involved in moral decision-making.

2. To try to prevent participants from beginning the decision process while reading the A and B options at their own pace, we chose to employ fixed presentation times for each option. Presentation times were established based on the mean reading times obtained for each option in a previous pilot study, in which a different group of participants (n = 15) were required to read each option silently on the computer screen and immediately

press the spacebar when they had finished. When asked, all participants included in this study reported having had enough time to complete the reading of each option. Note that option A was always shorter than option B in each dilemma.

REFERENCES

Aquinas, T. (1947). Summa Theologiae. II-II, Q. 64, art. 7. Benzinger Bros. Edition. (Original work published in 1265–1272.)

Borg, J., Hynes, C., Van Horn, J., Grafton, S., & Sinnott-Armstrong, W. (2006). Consequences, action, and intention as factors in moral judgments: An fMRI investigation. *Journal of Cognitive Neuroscience, 18,* 803–817.

Boyle, J. (2004). Medical ethics and double effect: The case of terminal sedation. *Theoretical Medicine, 25,* 51–60.

Braunack-Mayer, A. J. (2001). What makes a problem an ethical problem? An empirical perspective on the nature of ethical problems in general practice. *Journal of Medical Ethics, 27,* 98–103.

Chen, P., Qiu, J., Li, H., & Zhang, Q. (2009). Spatiotemporal cortical activation underlying dilemma decision-making: An event-related potential study. *Biological Psychology, 82,* 111–115.

Ciaramelli, E., Muccioli, M., Ladavas, E., & di Pellegrino, G. (2007). Selective deficit in personal moral judgment following damage to ventromedial prefrontal cortex. *Social Cognitive and Affective Neuroscience, 2,* 84–92.

Cunnington, R., Bradshaw, J. L., & Iansek, R. (1996). The role of the supplementary motor area in the control of voluntary movement. *Human Movement Science, 15,* 627–647.

Cushman, F., Young, L., & Greene, J. D. (2010). Multi-system moral psychology. In J. Doris & the Moral Psychology Research Group (Eds.), *The moral psychology handbook* (pp. 47–71). New York: Oxford University Press.

Cushman, F., Young, L., & Hauser, M. (2006). The role of conscious reasoning and intuition in moral judgment: Testing three principles of harm. *Psychological Science, 17,* 1082–1089.

Cuthbert, B. N., Schupp, H. T., Bradley, M. M., Birbaumer, N., & Lang, P. J. (2000). Brain potentials in affective picture processing: Covariation with autonomic arousal and affective report. *Biological Psychology, 52,* 95–111.

Damasio, A. (1994). *Descartes' error: Emotion, reason, and the human brain*. New York: Putnam.

Ernst, M., & Paulus, M. P. (2005). Neurobiology of decision making: A selective review from a neurocognitive and clinical perspective. *Biological Psychiatry, 58,* 597–604.

Feldman Barrett, L., & Fossum, T. (2001). Mental representations of affect knowledge. *Cognition and Emotion, 15,* 333–363.

Foot, P. (1967). The problem of abortion and the doctrine of double effect. *Oxford Review, 5,* 5–15.

Fumagalli, M., Vergari, M., Pasqualetti, P., Marceglia, S., Mameli, F., Ferrucci, R., et al. (2010). Brain switches utilitarian behavior: Does gender make the difference? *PLoS ONE, 5,* e8865.

Gillon, R. (1999). When doctors might kill their patients: Foreseeing is not necessarily the same as intending. *British Medical Journal, 318,* 1431–1432.

Gratton, G., Coles, M. G., & Donchin, E. (1983). A new method for off-line removal of ocular artifact. *Electroencephalography and Clinical Neurophysiology, 55,* 468–484.

Greene, J. D. (2009). Dual-process morality and the personal/impersonal distinction: A reply to McGuire, Langdon, Coltheart, and Mackenzie. *Journal of Experimental Social Psychology, 45,* 581–584.

Greene, J. D., Morelli, S. A., Lowenberg, K., Nystrom, L. E., & Cohen, J. D. (2008). Cognitive load selectively interferes with utilitarian moral judgment. *Cognition, 107,* 1144–1154.

Greene, J. D., Nystrom, L. E., Engell, A. D., Darley, J. M., & Cohen, J. D. (2004). The neural bases of cognitive conflict and control in moral judgment. *Neuron, 44,* 389–400.

Greene, J. D., Sommerville, R. B., Nystrom, L. E., Darley, J. M., & Cohen, J. D. (2001). An fMRI investigation of emotional engagement in moral judgment. *Science, 293,* 2105–2108.

Haidt, J. (2001). The emotional dog and its rational tail: A social intuitionist approach to moral judgment. *Psychological Review, 108,* 814–834.

Haidt, J. (2003). The moral emotions. In R. J. Davidson, K. R. Scherer, & H. H. Goldsmith (Eds.), *Handbook of affective sciences* (pp. 852–870). New York: Oxford University Press.

Hauser, M., Cushman, F., Young, L., Jin, R. K., & Mikhail, J. (2007). A dissociation between moral judgments and justifications. *Mind and Language, 22,* 1–21.

Huebner, B., Dwyer, S., & Hauser, M. (2009). The role of emotion in moral psychology. *Trends in Cognitive Sciences, 13,* 1–6.

Karim, A. A., Schneider, M., Lotze, M., Veit, R., Sauseng, P., Braun, C., et al. (2010). The truth about lying: Inhibition of the anterior prefrontal cortex improves deceptive behavior. *Cerebral Cortex, 20,* 205–213.

Koenigs, M., Young, L., Adolphs, R., Tranel, D., Cushman, F., Hauser, M., et al. (2007). Damage to the prefrontal cortex increases utilitarian moral judgements. *Nature, 446,* 908–911.

Lang, P. J., Bradley, M. M., & Cuthbert, B. N. (2008). *International affective picture system (IAPS): Affective ratings of pictures and instruction manual*. Technical Report A-8, University of Florida, Gainesville, FL.

Lotto, L., Manfrinati, A., & Sarlo, M. (submitted). A standardized set of 60 moral dilemmas based on the principle of the double effect. *Behavior Research Methods*.

McGuire, J., Langdon, R., Coltheart, M., & Mackenzie, C. (2009). A reanalysis of the personal/impersonal distinction in moral psychology research. *Journal of Experimental Social Psychology, 45,* 581–584.

Mendez, M. F., Anderson, E., & Shapira, J. S. (2005). An investigation of moral judgement in frontotemporal dementia. *Cognitive and Behavioral Neurology, 18,* 193–197.

Moll, J., Zahn, R., de Oliveira-Souza, R., Krueger, F., & Grafman, J. (2005). The neural basis of human moral cognition. *Nature Reviews Neuroscience, 6,* 799–809.

Moore, A., Clark, B., & Kane, M. (2008). Who shalt not kill? Individual differences in working memory capacity, executive control, and moral judgment. *Psychological Science, 19,* 549–557.

Paulus, M. P. (2005). Neurobiology of decision-making: Quo vadis? *Cognitive Brain Research, 23,* 2–10.

Pizarro, D. (2000). Nothing more than feelings? The role of emotions in moral judgment. *Journal for the Theory of Social Behavior, 30,* 355–375.

Rösler, F., & Heil, M. (1991). Toward a functional categorization of slow waves: Taking into account past and future events. *Psychophysiology, 28,* 344–358.

Ruchkin, D. S., Munson, R., & Sutton, S. (1982). P300 and slow wave to a message consisting of two events. *Psychophysiology, 19,* 629–642.

Shibasaki, H., & Hallett, M. (2006). What is the Bereitschaftspotential? *Clinical Neurophysiology, 117,* 2341–2356.

Sinnott-Armstrong, W. (1987). Moral realisms and moral dilemmas. *The Journal of Philosophy, 84,* 263–276.

Skrandies, W. (1989). Data reduction of multichannel fields: Global field power and principal components analysis. *Brain Topography, 2,* 73–80.

Thomson, J. (1985). The trolley problem. *Yale Law Journal, 94,* 1395–1415.