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CRITICAL PERSPECTIVES

Discovering the Neural Nature of Moral Cognition? Empirical, Theoretical, and Practical Challenges in Bioethical Research with Electroencephalography (EEG)

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Abstract In this article we critically review the neural mechanisms of moral cognition that have recently been studied via electroencephalography (EEG). Such studies promise to shed new light on traditional moral questions by helping us to understand how effective moral cognition is embodied in the brain. It has been argued that conflicting normative ethical theories require different cognitive features and can, accordingly, in a broadly conceived naturalistic attempt, be associated with different brain processes that are rooted in different brain networks and regions. This potentially morally relevant brain activity has been empirically investigated through EEG-based studies on moral cognition. From neuroscientific evidence gathered in these studies, a variety of normative conclusions have been drawn and bioethical applications have been suggested. We discuss methodological and theoretical merits and demerits of the attempt to use EEG techniques in a morally significant way, point to legal challenges and policy implications, indicate the potential to reveal biomarkers of psychopathological conditions, and consider issues that might inform future bioethical work.

Keywords Electroencephalography (EEG) · Brain imaging · Moral cognition · Normative ethics · Legal, practical and policy implications · Biomarkers

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Introduction

The study of moral cognition via neuroscientific methods has recently become of great interest to moral psychologists, neuroscientists, bioethicists, and philosophers alike. Due to the rapid advance of modern brain-imaging techniques such as functional magnetic resonance imaging (fMRI) and electroencephalography (EEG), novel means to access moral cognition are available. These techniques promise to shed new light on traditional moral questions by helping us to understand how effective moral cognition is embodied in the brain. As Michael Gazzaniga puts it: "Cognitive neuroscience has valuable information to contribute to the discussion of certain topics that have traditionally been taken up by bioethicists, namely, those issues in which brain science has relevant knowledge that should impact the ethical questions being debated" (2005, 141). However, the exact way in which neuroscience impacts our understanding of moral cognition remains unclear.

One of the challenges in empirically studying moral cognition lies in the fact that different normative ethical theories emphasize conflicting convictions of how to get things right. Of course, the question of what constitutes a moral judgement is itself in dispute. These normative ethical convictions can be roughly linked to different cognitive features and can, in a broadly conceived naturalistic attempt, be associated with different brain processes that are rooted in different networks and regions. Casebeer (2003), for example, suggests that different normative ethical theories can be linked to specific functions and networks in the brain. The role of particular cognitive features implied by different normative ethical theories (for example, the use of executive functions in goal-orientation), can be experimentally investigated. Now, if moral cognition is, for example, believed to be first and foremost a rational endeavour, being committed to "reason purely" about the demands of, say, Kant's categorical imperative, executive functioning stemming mostly from frontal brain regions is most pertinent. For advocates of utilitarianism such as Mill, on the other hand, a moral agent's most important ability is to recognize and compute utility functions; accordingly, an integration of pre-frontal, limbic, and sensory regions is essential to the manipulation of numerical values, as well as the coding of value itself. Yet others, such as virtue ethicists Plato and Aristotle, think of moral cognition roughly as the ability to reason well about which states of being would be most conducive to general human flourishing and to the individual good life in particular. This more deflationary process, then, focuses on the appropriate coordination of properly functioning cognitive sub-entities and can be seen as involving the whole brain.[1] One of the most strongly held contemporary neuroethical accounts is Neo-Humean or sentiment-based in nature, emphasizing the pivotal role of emotions and affects rather than reason and deliberation for moral cognition (Greene and Haidt 2002). Another, more inclusive, view takes moral cognition to be an evolved neural adaptation to social interactions, integrating reason and emotion. The moral brain is characterized as an integrative cognitive system, using a dynamic responsive equilibrium where reality and imagination shape human behaviour and experience (Gillett and Franz 2014).

When looking at such a mapping of moral cognition associated with different brain processes (cognitive or affective) which can be linked to certain brain regions, it becomes apparent how neuroimaging methods can yield evidence as to how measurable brain activity and moral cognition are related.

This linking of brain activity in certain regions to moral cognition suggests that neuroscientific evidence is not only expository as to how human beings de facto act but also reveals tenets of normative ethical theories. Doing bioethics in this way constitutes an attempt to draw conclusive relationships between neuroscientific observations and normative ethical theories—consequently, it is aimed at suggesting concrete prescriptions in bioethical debates. The general aim is to merge scientific descriptions and normative evaluations of human (and occasionally non-human) life. This branch of bioethics investigates both the significance of neuroscientific findings for the understanding of morality and the relevance of ethical considerations for determining the normative import of evidence from neuroscience. The former is concerned with neural and psychological mechanisms underlying ethical concepts and judgements, whereas the latter is concerned with the implications of those findings for moral practice.

In this article, we briefly review the neural mechanisms of moral cognition that have been studied via the paradigmatic imaging modality electroencephalography (EEG), discuss methodological merits and demerits of this technique, point to legal and practical applications, and consider issues that could potentially inform future experimental work. Our focus on EEG is designed to remedy the lack of an organized review of this technique (in contrast to work already done in fMRI: Mendez 2009; Pascual et al. 2013; Raine and Yang 2006) and attempts to mitigate the understandable bias, particularly when it comes to a non-specialized audience, against research using neuroimaging techniques.

Experimental Challenges: Using EEG Measures in the Study of Moral Decision-Making

While the most widely known neuroscientific studies of moral cognition make use of a neurological localization approach (Greene et al. 2001, 2004; Koenigs et al. 2007), work exploring the electrophysiological basis of moral cognition has found less exposure—both within academia and with the general public. Localization techniques such as fMRI attempt to determine which brain regions are active during a task by measuring changes in blood flow (Huettel et al. 2008); EEG measures the electrical currents continuously generated by

[1] See Casebeer (2003) for further details.

cortical layers, thus aiming at discovering when something happens in the brain. Although lacking the spatial resolution of fMRI, non-invasive techniques like EEG enable us to peek into sub-second processes, reflecting information processing related to stimulus presentation (Schomer and Lopes da Silva 2012). Moral cognition, involved in sub-second decision-making, is one such process. Studying moral cognition has thus led neuroscientists to take advantage of techniques with a high temporal resolution.

Event-Related Potentials and Moral Cognition

The relationship between deflections of the electrical field that are captured at the scalp and time-locked to a specific event (so called event-related potentials, or ERPs) and cognition has been known for over fifty years (Walter et al. 1964). Recently, there has been a surge of interest in studying ERPs related to moral cognition and decision-making in general. That is, both morally relevant and morally irrelevant decisions have been studied. Given its high temporal resolution, EEG allows for probing and describing the attentional, cognitive, and affective mechanisms immediately following or preceding the processing of, in the present case, a morally relevant stimulus. Furthermore, ERP techniques have increasingly gained importance as a means of studying consciousness itself or levels thereof. For example, EEG is used to determine the degree to which patients with so-called "disorders of consciousness" are in fact conscious, even in the absence of behavioural responses (Beukema et al. 2016). Considering that moral cognition is most likely dependent on conscious awareness—hence sharing fundamental mechanisms such as working memory or multisensory integration—it seems fit to use EEG to explore such types of processes. With increasing evidence of the importance of distributed semantic space (Huth et al. 2012) and oscillating activity with functional synchronization across the anterior and posterior cortices (Mogilner et al. 1993; Moll et al. 2005; Lenartowicz et al. 2016) in regards to awareness and attention, it seems likely that moral cognition would be similarly dependent upon some degree of binding and synchrony across these diverse areas of the brain, given its dependence on memory, (both working memory space and long-term stores) reasoning, and emotional state.[2]

[2] We are grateful to an anonymous reviewer for this point.

A typical ERP experimental setup involves the presentation of discrete (one at a time) and short (from milliseconds up to a few seconds) stimuli within a certain context. The stimuli to be processed are then presented several times in order to obtain a sufficiently high signal-to-noise ratio (Luck 2014). Given the noisy nature of the EEG signal, a significant number of samples is needed in order to obtain analysable data. In the case of moral decision-making experiments, the morally relevant stimulus, such as a picture or a word, is presented within a batch of other stimuli (a sequence of pictures pertaining to an action or a sentence depicting a behaviour) that give it a certain contextual relevance and that bear moral significance. The response to the morally laden stimulus is then subsequently analysed in order to infer the mechanisms subserving its processing. This allows examining the time-course of the decision-making processes and its different sub-stages. In the case of moral dilemmas, for example, it can be useful to disentangle whether decisions are based upon low-level features of the scenario (such as emotional salience) or reached through cognitive effort and referral to moral rules. This allows for drawing inferences or generating hypotheses about what kind of normative ethical theories cohere best with empirical evidence generated from recording EEG signals during a moral dilemma task.

Most of the ERP components have been thoroughly described and analysed. These can be roughly divided into early activity (50-200ms), such as the P50 (Nathan et al. 2007) or the N1-P2 complex (Näätänen and Picton 1987), and later activity, such as the P300 (Polich 2007), N400 (Kutas and Federmeier 2011), or the Late Positive Potential (LPP) (Cacioppo et al. 1994).

The former are usually, though not exclusively, associated with automatic processes and modulated by physical, low-level properties of the stimuli, while the latter are seen as a product of higher-order cognitive processes (Macnamara et al. 2009; Weinberg and Hajcak 2010). An illustration of some of the described components is sketched, for exemplification purposes, in Fig. 1. In this figure, the X-axis indicates the timing, measured in milliseconds, of each data point—typical recordings collect data anywhere between 200 and 1000 times per second. The recorded amplitudes are measured in microvolts and are indicated in the Y-axis. Different experimental manipulations impact different dimensions of the components (e.g., amplitude or timing).

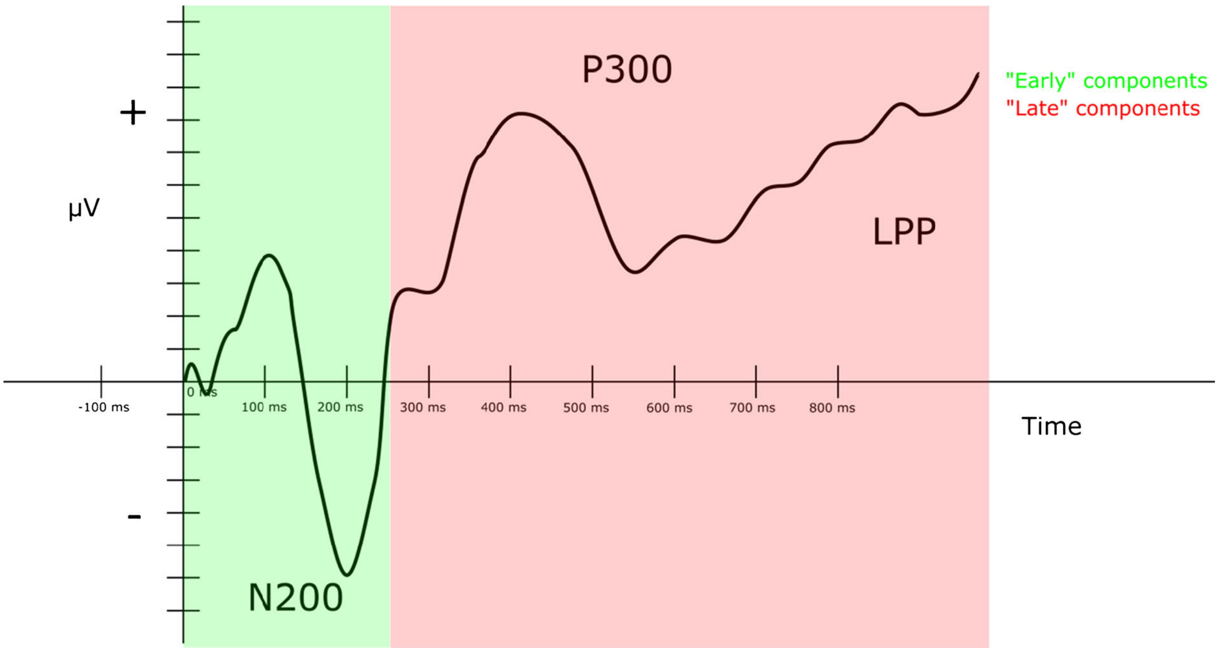

Fig. 1 Event-related Potentials (ERPs): Some of the Typical ERP Components Analysed in EEG Experiments

Early ERP Components

Several of these ERP components have been linked to, and studied within, the context of moral decision-making. It has been shown that the early component N200—a negative deflection occurring approximately 200 milliseconds after stimulus presentation—is larger for words reflecting a moral violation (independent of authority or rules) rather than a conventional (contingent on social constraints) violation (Lahat et al. 2012). This activity is usually considered to be a reflex of conflict monitoring and saliency processing—the automated orientation of perceptual and cognitive resources to sensory data (Botvinick et al. 2000; Harsay et al. 2012). At the same time, the N200 is also reported to differentially react to fair and unfair proposals in the ultimatum game: an economic reasoning experiment in which participants have to accept or reject the proposal of other participants regarding how to split a certain sum of money. Reactions to fair or unfair proposals have been interpreted as consistently reflecting moral attitudes. It has also recently been demonstrated that this early activity is modulated by prosocial and antisocial actions, pointing towards a rapid classification of the emotional saliency of the presented moral scenarios (Boksem and de Cremer 2010; Yoder and Decety 2014). The involvement of this very rapid differential processing of morally relevant stimuli has also been suggested by another research group (Sarlo et al. 2014), where the P260 component was shown to be sensitive to the affective distress felt during the decision-making process in "footbridge-style" moral dilemmas. This indicates that the electrophysiological activity is sensitive to the unpleasantness of the decision-making process. The same component seems to be sensitive to the consideration of legal consequences of moral behaviour, being larger in the case where there are no such consequences, indicating heightened affective conflict (Pletti et al. 2015). These authors have also shown how, in the condition where legal considerations matter, motor preparation is enhanced, as measured by the pre-response readiness potential ("Bereitschaftspotential"), a negative deflection occurring prior to pressing the button, reflecting readiness to act upon the scenario.

Although somewhat out of the scope of this article, it should be noted that the readiness potential has attracted major attention in the free-will debate, ever since Benjamin Libet first observed its importance for moral reasoning in the early 1980s. The fact that behaviour can be predicted from brain states preceding the perception of the conscious decision to act is crucial to the conceptualization of morality, given its dependency on intentionality and agency.

Later ERP Components

Despite the evidence for this early modulation of stimulus processing based on the stimulus characteristics and experimental conditions, the aforementioned and other studies have also shown how later stimulus processing, reflecting higher-level cognitive mechanisms, is involved in morally relevant scenarios. These include allocation of attentional resources to a particular stimulus, cognitive appraisal (i.e., evaluation of the stimulus following a set of rules), and re-appraisal (DeCicco et al. 2012; Shafir et al. 2015), or even the processing of semantic content and the detection of incongruences, that is, words that do not fit the overall meaning of the sentence.

In a way similar to the results found in the earlier components, the aforementioned LLP (a positive deflection occurring 300 milliseconds post-stimulus) seems to differentiate between prosocial and antisocial scenarios and is sensitive to the type of scenario presented, being modulated by perceived unpleasantness. Interestingly, cognitive empathy as well as guilt perception appears to modulate the amplitude of the LPP (Yoder and Decety 2014). Although this suggests that individual differences in empathic processing might underlie and modulate moral reasoning, further work presages that a disentanglement and clarification of the concept of empathy is needed in order to assess its specific role. More precisely, it seems that different facets of empathy (emotional and cognitive empathy) predict behaviour in different ways, producing conflicting data; therefore, generalizations should be taken with reservations (Decety and Cowell 2014).

These findings are consistent with previous studies demonstrating an N400 effect, typical of incongruence detection, to words inserted in objectionable statements in line with—or in conflict with—participants' reported values, followed as well by a modulation of the LPP (Van Berkum et al. 2009). The same overall pattern of modulation of both early and late onset components that is prevalent in the evaluation of words in moral transgression scenarios was again found in another recent study (Leuthold et al. 2015). In particular, the LPP was found to exhibit a higher amplitude for words considered to be morally unacceptable when compared to acceptable words in a given sentence. These findings replicate and extend an earlier work where prototypical social scenarios were used (Leuthold et al. 2012).

In sum, it seems clear that regardless of the stimulus type (linguistic or visual content), both early and late ERP components are modulated by different dimensions considered to be morally relevant. This seems to favour the idea that moral cognition implies both automatic and fast processing of presented stimuli as a means of rapidly categorizing them, as well as subsequent active appraisal and cognitive effort. This may present evidence in favour of viewing moral reasoning as a particularly complex type of processing with distinct and distributed spatio-temporal patterns, involving multiple regions (e.g., prefrontal, limbic, and parietal regions) and timescales (e.g., immediately and long after stimulus presentation).

Curiously, and following from the previous consideration, it is interesting that some particular components, such as the P300, have also been extensively used as a means to study consciousness itself, acting as a marker of conscious awareness under the "global workspace theory" and similar information-integration-based models (Baars et al. 2013; Dehaene and Changeux 2011; Edelman and Tononi 2000). More precisely, it has been suggested that this and later components are tightly linked to the binding problem, acting as a correlate of integration of information from different regions in the brain (Franklin et al. 2012). Using stimulus-locked paradigms such as the ones described above, it has also become possible to identify further potential mechanisms underlying information integration through the synchronization of firing patterns across neuronal populations. These firing patterns, although not strictly ERPs, reveal how oscillatory activity in several frequency bands can organize and support conscious events by supporting the propagation and integration of information across the brain (Steriade 2006).

Setbacks of EEG-Based Studies on Moral Cognition

From a methodological point of view, the use of EEG allows for a robust assessment of fast brain processes that affect moral cognition and decision-making. As such, and given its low cost and non-invasiveness, it would seem as if most experimental research ought to use EEG. However, it must be noted that despite its high temporal resolution, the precise localization of the activity itself (i.e., which particular neuronal populations are contributing to the signal) still suffers from some problems and limitations. Furthermore, as we have noted, most of this captured activity comes from cortical matter and a particular subset of layers. This means that large sets of regions (most of the subcortical structures, for example) and their processes remain impenetrable to EEG, being only accessible through the use of other neuroimaging techniques such as fMRI. Ideally, then, results from EEG studies should be complemented with relevant fMRI investigations to account for the low spatial resolution of EEG. Nonetheless, as can be seen in some of the aforementioned studies on moral reasoning (e.g., Yoder and Decety 2014), some techniques such as LORETA allow for the partial reconstruction of cortical sources of the signal captured at the scalp level. When used carefully, this can contribute to more spatial information regarding the regions involved in a particular type of processing, linking it to other studies resorting to techniques such as fMRI. A further method of solving what has become known as the EEG inverse problem of source localization is the weighted minimum-norm method (Song et al. 2006) which, like LORETA, aims to determine spatially the source (group of neurons) which are the source of the specific EEG activity being studied. Together, these methods attenuate the drawbacks of EEG, namely its poor spatial resolution.

The nature of the EEG signal makes it a rather noisy source of information and thus demands strict experimental setup and data-processing procedures. As a safe and conservative solution, the selection of the experimental technique must take into account the kind of problem that is being tackled and follow a rigorous experimental procedure in order to avoid collecting futile or potentially misleading data.

Aside from the fundamental implications of disentangling the neural mechanisms underlying moral decision-making—due to the attempt of naturalizing it through empirical data collection and modelling—both more theoretical and practical questions arise. These questions will be addressed in what follows.

Theoretical Challenges: The Normative Significance of EEG Studies on Moral Cognition

The discussed research on the neurological basis of morality has led to vigorous conclusions regarding, for example, the act of killing (Greene 2003) or punishment (Sunstein and Vermeule 2005). Much, however, has yet to be clarified both in terms of methodology and empirical data interpretation (Levy 2007). Moreover, the theoretical framework upon which such research is conducted needs further development.

Plea for More Theoretical Work

More theoretical work is needed in order to show how normative ethical theories relate to actual and hypothetical human behaviour and what role neuroscientific evidence can play in such an endeavour. For example, in the previously mentioned debate between deontology and utilitarianism, it is far from clear whether consulting hypothetical moral dilemmas in general, and the neuroscientific study of participant's reactions to such dilemmas in particular, can yield relevant conclusions as to what kind of normative ethical judgement actually underlies the decision-making processes in question (Kahane 2015), let alone determine which normative ethical theory ought to be favoured. Kahane suggests that when participants deliberate about, say, the infamous trolley dilemma, they are in fact not deciding between opposing utilitarian and deontological solutions, but they are engaging in a richer process of weighing opposing moral reasons. These may point to virtue ethical theories, though this is not Kahane's interpretation. Whether this broader process of moral reasoning can be tracked down by EEG experiments remains elusive.

Drawing Normative Conclusions from Descriptive Claims

A principle difficulty that arises from the interpretation of EEG data—likewise when interpreting data obtained from other neuroimaging techniques—is the frequently assumed objectivity that comes with visualizing brain activity. It is tempting to assume that statistical analysis of brain wave recordings allows the researcher, as it were, a direct glimpse into participants' minds. But the relationship between subjective mental states and electromagnetic signals is far from straightforward (Poldrack 2006).

The majority of neuroscientists lean towards a reductive view of the human mind, presuming that more-or-less direct inferences can be drawn from neuroscientific observations to subjective mental states.[3] On this robust

[3] This is by no means to assert that all neuroscientists are reductionists, or that neuroscience is ipso facto committed to reductionism. We merely claim that the prevalent view in neuroscience about the nature of the human mind is naturalistic.

naturalistic view, mental states are reducible to brain states and, as such, are susceptible to empirical investigation. It is thereby sometimes overlooked, however, that imaging studies are based on probabilistic covariances, not on causal relations, making direct inferences contentious—a problem that has been duly noted, methodologically speaking, by the neuroimaging community itself. This methodological predicament parallels and somewhat overlaps with what has been called the "reverse inference problem" (ibid.): an inductive method that entails extrapolating backwards from the observed brain activity to particular cognitive processes which are, however, not directly tested. Furthermore, the interpretation of EEG data depends on theoretical assumptions of the researcher and inevitable idiosyncrasies of the study design; results may also be subject to social and cultural contingencies.

From these difficulties in interpreting EEG data, methodological predicaments arise in making strong cases for supporting or debunking normative ethical theories that lean heavily on the empirical results of such neuroimaging studies. In light of this, it is important to be aware of the following two considerations when confronted with naturalistic arguments that attempt to draw normative conclusions from descriptive claims.

- Are the descriptive claims correct? This involves asking whether the experimental designs of neuroscientific studies are actually significant and thus able to capture what they aim to investigate.[4]
- Do the normative conclusions really follow? This involves asking whether the interpretation of the empirical data, given that the design is adequate, is sound.

Epistemic Values in Scientific Research

Pertinent to the aforementioned methodological predicaments in neuroscientific research on moral cognition, there is a substantial body of thought coming from philosophy of science that addresses the complex ways in which scientific practices, and the products of science, are interwoven with values. Since the 1950s and 1960s, it has been argued that science is inevitably to some extent governed by value judgements (Rudner 1953). For one, the application of scientific methods is value-laden. In the quest for empirical discoveries, methods are restrained according to (often implicitly presupposed) normative ethical convictions. For example, invasive or potentially harmful experiments on healthy human participants are disallowed even at the expense of potentially impeding the progress of finding a cure for cancer. Accordingly, it has been argued that besides logic and evidence, science is in need of additional guidance for theory choice (Churchman 1956). In order to account for this, the term "epistemic values" was introduced to encompass the values that were seen as acceptable in guiding scientific research and theory building (McMullin 1982).

More recently, Douglas has opted to abandon the ideal of value-free science altogether, particularly if value-free science is meant to include the rejection of epistemic values. We agree that there need not be (and perhaps cannot be) a science that is freed of epistemic values, and we concur that it would be good for science to allow for "more open discussion of the factors that enter into scientific judgements and the experimental process" (Douglas 2007, 121). Douglas acknowledges the methodological predicament of the naturalistic fallacy, alongside the difference between descriptive and normative statements, but she contends that:

> [t]his does not mean … that a descriptive statement is free from values in its origins. Value judgments are needed to determine whether a descriptive label is accurate enough and whether the errors that could arise from the description call for more careful accounts or a shift in descriptive language. Evidence and values are different things, but they become inextricably intermixed in our accounts of the world (ibid., 126).

So, in order to make sense of empirical discoveries, we are dependent on scientific interpretations of the acquired data, and these interpretations inevitably have a normative dimension.

Context-sensitivity

As we have argued, there is a peculiar relation between values and facts in empirically driven ethical research.

[4] Several philosophers have taken issue with Libet's insinuation that neuroscience suggests free will to be an illusion. Even though Libet himself remained moderate regarding the evidence against free will gathered from his studies, some of his successors have made much stronger claims, positing that neuroscience has shown that free will is but an illusory trick that the brain plays on us.

This calls for paying close attention to the contingencies governing the de facto norms and social structures of everyday life, since these are at issue in empirically driven research on moral cognition (Wagner and Northoff 2015). Any scientific endeavour inevitably presupposes certain epistemological and metaphysical commitments because agents are shaped by a particular context—perceiving and interpreting the world around themselves in a great many different ways. In trying to determine the normative significance of neuroscientific evidence, the relatively austere individual and idiosyncratic social points of view cannot be altogether disregarded. In other words, the social, cultural, and political contexts in which ethical questions are posed and empirically driven answers are proposed need to be taken into account.

When aiming at drawing normatively significant conclusions from neuroscientific data, what we call a "content–context relationship" needs to be considered. Merely looking at EEG data in a vacuum, collected during a moral cognition task (thus focusing on the content), as investigated in the neuroscience of ethics, does not reveal how these empirical observations stand in relation to particular moral values (the relevant context), as discussed in moral philosophy. For example, observing an N200 effect tells us something about the cognitive components implicated in a particular moral judgement, such as the automated orientation of perceptual and cognitive resources to sensory data. Hence, the EEG data are considered and interpreted within a neuroscientific context. However, these empirical interpretations do not by themselves reveal anything about the normative significance of the data when weighing, say, utilitarianism and deontology. Here the gap needs to be bridged between the respective content that arises when inferring from the purely descriptive level of cognitive functions to the normative context within which the former are set and occur. To reduce normative ethical theories to neural and cognitive functions would thus be to absorb the normative realm within the descriptive level and ultimately entails a reduction of context to content.

Most of the discussed EEG-based studies on moral cognition focus exclusively on particular stimuli that bear moral significance, thereby, however, disregarding larger questions such as: in which kind of social and cultural setting are the stimuli presented, and how do they stand in relation to generally accepted sociocultural norms in a given setting? Such omission calls for paying closer attention to context-sensitivity as one criterion for the possibility of inferring normative conclusion from neuroscientific evidence; this has to be accounted for both experimentally and conceptually.

Furthermore, a great proportion of the experimental conditions in EEG studies focuses on intra-individual differences. They examine the variability between participants in their responses to moral dilemmas. This bias can somewhat be explained by the fact that repeated-measures designs (i.e., designs where the same subjects are stimulated with different conditions, reflecting, for example, consequentialist or deontological approaches) are experimentally more economical and easy to set up compared to independent-sample designs (i.e., designs targeting inter-individual differences between distinct groups, such as when comparing healthy controls and psychopaths). Nonetheless, the latter are still present in the literature and make important contributions that remain undetected in intra-individual experiments. For example, a recent study found that, contrary to the prevailing view that people who endorse non-utilitarian judgements to moral dilemmas are committing an error, there is evidence suggesting that participants who respond in a utilitarian fashion possess personality traits that are widely seen to be highly immoral. Participants responded to a battery of personality assessments and a set of dilemmas that pit utilitarian and non-utilitarian options against each other. Interestingly, those participants who indicated greater endorsement of utilitarian solutions also had higher scores on measures of psychopathy, Machiavellianism, and life meaninglessness (Bartels and Pizzaro 2011). The authors rightly suggest that these results indicate a need to be methodologically wary of favouring an experimental structure that equates the quality of moral judgements with responses that are endorsed primarily by individuals who are likely perceived as less moral as they possess traits such as callousness and manipulativeness. Adopting such a method can lead to the counterintuitive inference that "correct" moral judgements are most likely to be made by individuals that are simultaneously most likely to possess character traits generally perceived as immoral.

The aforementioned shortcomings of EEG studies on moral cognition suggest once more the need to complement robust naturalistic forms of empirically driven ethical research with a thoroughly argued conceptual-normative analysis that does justice to carefully situating ethical concepts within their relevant social, cultural, and political contexts.

Keeping in mind the previously discussed merits and demerits of EEG-based studies on moral cognition, we reach the following broad intermediate results. (1) Exploring the neural underpinnings of moral cognition is justifiably believed to lead to empirically-informed, more sophisticated moral theories. In that regard, the previously discussed experimental literature employing EEG as a marker for moral cognition can shed new light on traditional issues in normative ethics. (2) The overall goal to naturalize ethics in this way is to show how our moral practices and the underling moral theories are features based on the complexity of the human brain and can as such be scrutinized scientifically. (3) Crucial in this regard is that experiments are designed so as to take into account the aforementioned context-sensitive nature of moral cognition, as well as to maximize ecological validity—a difficulty that consists in the nature of experiments conducted under artificial lab situation that bear little resemblance to real-life moral decision-making. This can be alleviated by designing experiments as realistically as possible and by implementing incentives that have real-life significance, as is practiced in economic decision-making experiments. (4) The identification of neural correlates of moral cognition is partly dependent on—certainly connected to—having a moral theory in place when searching for its neural underpinnings. This has the advantage of enabling the researcher to eliminate certain moral theories as neurobiologically unrealistic. If, for example, a theory requires a high demand of reason and deliberation, but experiments consistently show that morally praiseworthy decisions are reached via fast heuristics, a reason-based theory would appear to be at odds with the evidence. (5) Particular cognitive features like executive functions, (e.g., goal-orientation), emphasized by different normative ethical theories, are investigated experimentally in order to reveal tenets of these different theories. If, as deontological theories assume, moral cognition is governed by “reason purely” about the demands of, say, Kant’s categorical imperative, executive functioning stemming mostly from frontal brain regions is most pertinent. According to utilitarianism as proposed by Mill, a moral agent’s most important ability is to recognize and compute utility functions; accordingly, an integration of prefrontal, limbic, and sensory regions is essential to the manipulation of numerical values and to the coding of value itself. Virtue ethics theories going back to Aristotle think of moral cognition roughly as the ability to reason well about what states of being would be most conducive to human flourishing. Moral concerns thus relate to what we ought to do and think so as to function well as human beings, involving an appropriate coordination of properly functioning cognitive sub-entities that are distributed throughout the whole brain. (6) When weighing these theories, it is important not to fall prey to a naive naturalistic reductionism or to smuggle in an agenda by trying to identify the neural correlates of exactly that form of moral cognition that best fits the theory that was assumed to be most plausible in the first place. So, additional argumentative work is needed in order to offer independent reasons as to which theory is conceptually most persuasive. (7) The discussed neuroscientific evidence thus far suggests that moral cognition is a process widely distributed throughout the entire brain and not restricted to either reason or emotion. To a first approximation, then, when seeking a theory that coheres best with current evidence, we do well to cast our net widely enough so as to include all aspects of moral reasoning.

Practical Implications

Apart from the impact that EEG studies have on normative ethical theory, what might be the role that evidence from such studies can play regarding moral questions that figure relevant in clinical or legal settings? Statistically speaking, inter-individual differences in basic information processing or brain functioning, such as sensory processing and integration (Stevenson et al. 2012), for example, can account for a large amount of variance in moral decision-making which falls outside the norm. This, in turn, could theoretically and practically inform decisions on legal transgressions and mental health.

Legal Challenges

Historically, there have been attempts to introduce lie-detection techniques based on both physiological measures and neuroimaging evidence into the court room. The former has precedents of being accepted legally, although seldom and restrictedly, but the latter has encountered vivid opposition—for reasons which seem obvious. While the philosophical definition of lying is far from settled (Kagan 1998), its legal role is rather clear-cut and its reliable detection something that the justice system would immensely benefit from. However, the possibility of false positives due to an over-reliance on technology is unappealing. In a similar way, as seen in the recent hype of psychopathy research, demonstrating that a particular suspect has brain lesions or malformations that correspond to impaired emotional processing or inhibitory mechanisms places a huge burden on the demonstration of imputability (Hughes 2010), or lack thereof as the case may be.

As it is generally the case with findings of this nature, ethical considerations surrounding the implications for responsibility and privacy arise. To begin with, issues of criminal responsibility and free will, specifically in the arena of the criminal court, have been challenged by recent neuroscientific findings on moral decision-making (Aharoni et al. 2011; Koenigs et al. 2012). This can be illustrated with the treatment of psychopathy and criminal responsibility. Psychopaths have been characterized as persons with a strong lack of empathy or guilt, shallow affect, manipulative behaviour with superficial charm, delusions of grandeur, a parasitic use of others, early onset of antisocial behaviour, and other similar traits (Hare 2003). Recent imaging studies have associated the ventromedial prefrontal cortex with interpersonal deficits as well as an antisocial lifestyle and actions, while the mirror neuron network has been linked to interpersonal deficits and antisocial lifestyle (Contreras-Rodriguez et al. 2014; Li et al. 2014; Motzkin et al. 2011). In addition, EEG studies have associated forebrain circuit dysfunction with psychopathy (Cummings 2015); whereas fMRI studies have shown amygdala dysfunction in psychopaths (Thompson et al. 2014). These studies show dysfunction in anatomical and physiological components in the psychopathic brain. The practical implication, however, is the issue of how these empirical findings bear on responsibility in the legal context. Many support the use of the evidence in the courtroom to negate, or at least mitigate, the psychopaths' *mens rea* with respect to crime. The opposite view, affirming that despite clear abnormalities in the brains of these offenders, a reliable step from neuroscientific findings to criminal responsibility has not yet been made, has many supporters. The debate continues.

The general implications of these empirical findings on criminal and moral responsibility and free will are disputed. In one view, a more careful, logical link from neuroscientific findings to conclusions about responsibility is needed, without, as Stephen Morse states, falling prey to a "brain overclaim syndrome" in which unsustained claims about neuroscientific implications are made. "Brains do not commit crimes;" Morse claims, "people commit crimes" (Morse 2005). One possible response to this claim states that although people commit crimes, it is their brain that determines their behaviour, and so an abnormal brain produces, as it were, abnormal behaviour. To separate the brain from behaviour would imply a second seat of criminal responsibility, positing the existence of an immaterial mind of sorts. According to most neuroscientists and philosophers alike, this dualistic view is false; some even claim that science has proven it to be so (Martell 2009; Kendler 2005).

Policy Issues

A further ethical problem with implications for policymakers arises from data privacy and security. Regulations are needed as to who will have access to generated data and who will be granted access to collect such data, and for what purpose. As has been shown in cases of psychopathy (Aharoni et al. 2011; Koenigs et al. 2012) and alcohol intoxication (Duke and Bègue 2015), certain groups produce more consequentialist responses than controls. These studies have induced much discussion on underlying reasons for these differences: is the more consequentialist response pattern due to an increased reasoning capacity or due to a decreased emotional capacity? The prevailing opinion relates to impaired emotional activity. From this hypothesis, these specific populations are being branded with an impairment which may have practical consequences in their everyday lives. For example, would a potential employer be within their rights to require an applicant to undergo an EEG moral dilemma study, similar to the ones mentioned above, in the hope of determining psychopathic brain patterns? Will these neuroscientific findings relieve a person with a high *Psychopathy Checklist-Revised* score from criminal responsibility, while also burdening them with decreased personal and professional opportunities? Along with the possible implications of these neuroscientific findings described above, how will certain people be differentiated from the majority, and how will possible issues of discrimination be countered?

Related to the point of impaired criminal responsibility, this method of research applied to moral dilemmas may pose risks to the general decision-making capacity of patients and at-risk populations. Recently, several studies have provided evidence to support the hypothesis that intact emotional activity in the brain is necessary for decision-making in daily life (Bechara 2004; Chang and Sanfey 2008; Heilman et al. 2010). These studies show that intact emotional processing is important for decision-making in financial matters and in social settings, but also on the appraisal of the consequences of a decision at the level of a “gut reaction” (Chang and Sanfey 2008). Since these neuroscientific studies of moral dilemmas expose processing in the brain of emotions related to these dilemmas, and also since emotional processing has been shown to be vital to everyday decision-making, the potential for the exploitation of individuals through its use exists. For example, it is possible that this experimental paradigm could be used to justify the classification of an individual, such as an elderly parent, as incompetent regarding financial decisions by their greedy adult child. Such cases of strategizing to seize control of an estate for one’s one ends have been commonplace. However, the ability of moral dilemma experiments to expose deficits in emotional activity and its consequences creates a new tool in the exploitation of vulnerable populations, as mentioned. For this reason, as well as the ones previously stated regarding criminal responsibility, close attention must be paid towards the implications of the neuroscientific findings of moral dilemmas on personal responsibility and autonomy.

Biomarkers

EEG studies also have the potential to discover biomarkers of mental illnesses by empirically measuring biological processes that can be quantified in a precise and reproducible fashion (Leiser et al. 2011). These indicators have been used to diagnose diseases and to predict clinical outcomes of treatments (Kuhlmann and Wensing 2006). Neuroimaging biomarkers have, for the most part, focused on identifying neural functions associated with psychopathology. FMRI and positron emission tomography (PET) have been used to identify biomarkers of psychopathology, though the interest in and capacity for EEG to do the same have recently soared. The reasons for this are as follows. To begin with, recent advances in software and computer systems for the processing of EEG signals and their visualization have improved the spatial information drawn from this continuous signal, which was always considered the weakness of EEG. With these ongoing advances in its supporting technology (most significantly, the aforementioned LORETA), EEG is now able to provide data with both high temporal and somewhat improved spatial resolution. EEG becomes increasingly more effective in detecting where in the cortex the activity on the scalp comes from, which enables it to identify fast changes in brain activity. Nevertheless, there is still a certain degree of spatial constraint (McLoughlin et al. 2014). Secondly, as EEG is a much lower-cost method than fMRI—costs per participant are approximately $45 versus $650 for fMRI—larger sample sizes are possible, which are required for identifying biomarkers. Finally, EEG is the most portable and non-invasive of all the neuroimaging modalities and allows for participants with metal in their body, which fMRI, for example, does not. Also, with new developments in EEG sensors and systems, the feasibility of testing individuals previously considered difficult, such as children or infants, has improved. Therefore, due to low cost, portability, and advances in EEG equipment and computational software, the use of EEG for discovering biomarkers of psychopathology has become promising for the future diagnosis and treatment of neurological and psychiatric conditions.

The above-described challenges (summarized in Table 1) are of an interdisciplinary nature and strongly suggest that policymakers, healthcare providers and the legal system need not only be well-informed about the empirical foundations and limitations of brain-imaging techniques such as EEG, but are also in need of consulting complementary work from bioethicists that enables an instructive assessment of these techniques from an ethical point of view.

Conclusion

In this article, we pointed to EEG as an informative neuroimaging technique bearing relevance to bioethical research. EEG allows for probing and describing the cognitive, affective, and attentional mechanisms immediately following or preceding the processing of morally relevant stimuli. When compared to other neuroimaging techniques (such as fMRI or PET), EEG has methodological and practical advantages; it is mostly noninvasive, has superb temporal resolution and lower costs, and it is relatively easily accessible to participants and patients alike. However, despite EEG’s temporal precision, there are limitations in its spatial resolution, leading to problems with precisely localizing the measured

Table 1 Empirical, Theoretical, and Practical Challenges in EEG-Based Studies on Moral Cognition

Level	Challenges
Empirical	Noisy EEG signal
	Lack of precise localization of brain activity
	Reverse inference problem
	Inter-individual differences
	False positives
Theoretical	Link between ethical theory and human behavior
	Drawing normative conclusions from descriptive claims
	Epistemic values in research
	Context-sensitivity
Practical	Lie detection
	Criminal responsibility
	Data privacy and security
	Discrimination against minority groups
	Biomarkers

brain activity. Since most of the captured brain activity comes from a very specific set of neuronal populations, large groups of regions and their processes remain inaccessible to EEG; these regions can only be mapped through the use of other techniques such as fMRI. Furthermore, the EEG signal in itself is inherently noisy, demanding a strict experimental setup and careful data-processing procedures. The selection of the experimental technique must also take into account the kind of problem the researcher is tackling and follow a thorough experimental procedure in order to avoid unsustainable conclusions. When these measures are taken, informative evidence can be gathered from EEG studies on moral cognition that might be able to open up new perspectives that can contribute to successfully shedding new light on bioethical problems.

However, an inherent predicament when relying on neuroscientific evidence in studying moral cognition is the contentious way in which norms and facts are related. EEG studies are based on probabilistic covariances, not on causal connections, making direct inferences from objective brain activity to subjective mental states problematic. In trying to determine the normative significance and import of evidence gathered from EEG studies, the relatively austere individual and idiosyncratic social and cultural points of view must be taken into account. Therefore, the social and cultural contexts in which ethical questions are posed and empirically driven answers are proposed must theoretically be taken into consideration and practically accounted for when designing experimental paradigms.

In light of the discussed challenges, it seems obvious that current neuroscientific findings are not conclusive enough to allow for a decisive verdict as to which moral theory coheres best with how the brain works. Nevertheless, there is considerable evidence suggesting that an empirically-informed Aristotelian virtue theory coheres best with what is so far known about brain functions during moral cognition. Virtue ethics theories are widely believed to have the richest moral psychology of the major moral theories, as reason, deliberation, emotion, and affect are all integral to living good and virtuous lives. This fits well with the discussed EEG studies indicating that moral cognition is a large-scale distributed brain process that cannot be reduced to certain areas or functions. Furthermore, it currently appears that the most ecologically valid experimental designs support the hypothesis that moral cognition is a large-scale brain affair depending on the appropriate coordination of many areas. Casebeer and Churchland (2003) point to research at a range of levels of organization from synapses to neurons to brain areas and systems, indicating that the organism which best triangulates norms will be one that uses (1) multi-modal signals (2) conjoined with appropriately cued executive systems that (3) share rich connections with affective and conative brain structures (4) which draw upon conditioned memories (5) and insight into the minds of others so as to (6) think about and actually behave in a manner enabling it to function as best it can. They emphasize that these capacities do have neural correlates, but generally such correlates will be multifaceted high-order functional relationships distributed throughout the brain. The discussed evidence also indicates that, contrary to deontology, there is most likely no such thing as a "pure reason" capacity and that emotion is integral to moral cognition. Contrary to utilitarianism, it appears that utility calculations by themselves are insufficient for moral cognition.

Tackling bioethical issues with the help of consulting evidence from EEG-based studies on moral cognition can be a valuable complementary source for normative ethical theory and bears the potential of having profound implications on legal, health care, and policy issues. These include determining criminal responsibility, the potential discovery of biomarkers for psychopathological conditions, and concerns on data privacy. To account for the methodological and theoretical complexity of studies with such wide-ranging conclusions, there is a strong need of further interdisciplinary research in which bioethicists can play a pivotal role.

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