The Neural Correlates of Third-Party Punishment

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SUMMARY

Legal decision-making in criminal contexts includes two essential functions performed by impartial “third parties:” assessing responsibility and determining an appropriate punishment. To explore the neural underpinnings of these processes, we scanned subjects with fMRI while they determined the appropriate punishment for crimes that varied in perpetrator responsibility and crime severity. Activity within regions linked to affective processing (amygdala, medial prefrontal and posterior cingulate cortex) predicted punishment magnitude for a range of criminal scenarios. By contrast, activity in right dorsolateral prefrontal cortex distinguished between scenarios on the basis of criminal responsibility, suggesting that it plays a key role in third-party punishment. The same prefrontal region has previously been shown to be involved in punishing unfair economic behavior in two-party interactions, raising the possibility that the cognitive processes supporting third-party legal decision-making and second-party economic norm enforcement may be supported by a common neural mechanism in human prefrontal cortex.

INTRODUCTION

Though rare in the rest of the animal kingdom, large-scale cooperation among genetically unrelated individuals is the rule, rather than the exception, in Homo sapiens (Henrich, 2003). Ultrasociality and cooperation in humans is made possible by our ability to establish social norms—widely shared sentiments about appropriate behavior in two-party interactions, raising the possibility that the cognitive processes supporting third-party legal decision-making and second-party economic norm enforcement may be supported by a common neural mechanism in human prefrontal cortex.
exchange, punishes the transgressor at some significant additional cost to himself. These findings have specifically highlighted the importance of reward and emotion-related processes in fueling cooperative behavior (Seymour et al., 2007). However, how—or even whether—neural models of economic exchange in dyadic interactions apply to impartial, third-party legal decision-making is currently unknown (Fehr and Fischbacher, 2004a). Furthermore, the importance of uncovering neural mechanisms underlying third-party punishment is underscored by the proposal that the development of stable social norms in human societies specifically required the evolution of third-party sanction systems (Bendor and Swistak, 2001).

Given that, in great measure, criminal law strives toward the stabilization and codification of social norms, including moral norms, in legal rules of conduct (Robinson and Darley, 1995), moral decision-making is inherently embedded into the legal decision-making process. The relevance of moral decision-making to an investigation of legal reasoning is highlighted by experimental findings which suggest that individuals punish according to so-called “just deserts” motives; i.e., in proportion to the moral wrongfulness of an offender’s actions (Alter et al., 2007; Carlsmith et al., 2002; Darley and Pittman, 2003). As such, the seminal work of Greene and others—which has demonstrated distinct contributions of emotion-related and cognitive control-related brain regions to moral decision-making (Greene et al., 2001, 2004; Heekeren et al., 2003, 2005; Moll et al., 2002a, 2002b)—is germane to the study of legal decision-making. However, despite the conceptual overlap between moral and legal reasoning, the latter process is not entirely reducible to the former (Hart, 1958; Holmes, 1991; Posner, 1998; Robinson, 1997; Robinson and Darley, 1995). Indeed, whereas determining blameworthiness may in many cases fall under the rubric of moral decision-making, the distinctive core and distinguishing feature of legal decision-making is the computation and implementation of a punishment that is appropriate both to the relative moral blameworthiness of an accused criminal offender, and to the relative severity of that criminal offense (Robinson, 1997; Robinson and Darley, 1995). The present study is focused on elucidating the neural mechanisms underlying this third-party, legal decision-making process.

In this study, we used event-related fMRI to reveal the neural circuitry supporting third-party decision-making. Given that these two legally distinct judgments are rendered on the basis of differing information and considerations (Lafave et al., 2007), we were particularly interested in determining whether these two decision-making processes may rely on at least partly distinct neural systems. To address this issue, we scanned 16 participants while they determined the appropriate punishment for actions committed by the protagonist (named “John”) in a series of 50 written scenarios. Each of these scenarios belonged to one of three categories: Responsibility (R), Diminished-Responsibility (DR), and No-Crime (NC). Scenarios in the Responsibility set (n = 20) described John intentionally committing a criminal action ranging from simple theft to rape and murder. The Diminished-Responsibility set (n = 20) included actions of comparable gravity to those described in the Responsibility set but also contained mitigating circumstances that may have excused or justified the otherwise criminal behavior of the protagonist by calling his blameworthiness into question. The No-Crime set (n = 10) depicted John engaged in noncriminal actions that were otherwise structured similarly to the Responsibility and Diminished-Responsibility scenarios (scenarios available as Supplemental Experimental Procedures). Participants rated each scenario on a scale from 0–9, according to how much punishment they thought John deserved, with “0” indicating no punishment and “9” indicating extreme punishment. Two groups of 50 scenarios (equated for word length between conditions and between groups) were constructed and their presentation counterbalanced across the 16 participants. The Responsibility set of group 2 consisted of group 1 Diminished-Responsibility scenarios for which the mitigating circumstances had been removed, while the Diminished-Responsibility set of group 2 consisted of group 1 Responsibility scenarios with mitigating circumstances added. Thus, each criminal scenario (e.g., depicting theft, assault or murder) in the Responsibility and Diminished-Responsibility condition was created by modifying identical “stem” stories, with salient details such as magnitude of harm matched between conditions.

RESULTS

Behavioral Data

Behavioral data showed a significant effect of scenario category on punishment ratings \( [F(1,15) = 358.61, p < 0.001] \) (Figure 1), with higher mean ratings for the Responsibility (mean = 5.50, SE = 0.22) as compared with the Diminished-Responsibility scenarios (Mean = 1.45, SE = 0.21) \((p < 0.001,\text{ paired t test})\), indicating that assessed punishment was strongly modulated by the protagonist’s criminal responsibility. However, the fact that the mean punishment rating for the Diminished-Responsibility condition was greater than 0 suggests that some participants still attributed some blameworthiness to the protagonist despite the

![Figure 1. Punishment and Arousal Ratings for Each Scenario Type](image-url)
extenuating circumstances. To examine the subjective emotional experience elicited by the scenarios, all participants completed postscan ratings of emotional arousal for each scenario. These ratings also demonstrated an effect of condition [$F(1,15) = 94.61, p < 0.001$] (Figure 1), with greater mean arousal scores for the Responsibility (Mean = 4.83, SE = 0.41) compared to the Diminished-Responsibility scenarios (Mean = 3.48, SE = 0.35) ($p < 0.001$, paired t test). Additionally, we found a significant interaction between rating type (punishment versus arousal) and condition (Responsibility versus Diminished-Responsibility) [$F(1,15) = 68.8, p < 0.001$] such that, while the punishment and arousal ratings were not significantly different for the Responsibility scenarios ($p > 0.05$, paired t test), punishment ratings were significantly lower than the arousal ratings for the Diminished-Responsibility scenarios ($p < 0.001$, paired t test) (Figure 1). Lastly, we found a main effect of scenario condition on reaction times (RTs) [$F(1,15) = 21.87, p < 0.001$], such that RTs were shortest for the No-Crime condition and longest for the Diminished-Responsibility condition (Mean, SE for: Responsibility = 12.69 s, 0.46; Diminished-Responsibility = 13.76 s, 0.46; No-Crime = 11.12 s, 0.44; respectively) (all paired comparisons $p < 0.01$).

fMRI Data: Criminal Responsibility

To identify brain regions that were sensitive to information about criminal responsibility, we contrasted brain activity between Responsibility and Diminished-Responsibility scenarios. The resulting statistical parametric map (SPM) revealed an area of activation in the right dorsolateral prefrontal cortex (rDLPFC, Brodmann Area 46, peak at Talairach coordinates 39, 37, 22 [x,y,z]; Figure 2A) that was significantly more activated in the Responsibility as compared with the Diminished-Responsibility condition. Time course analyses of peak activation differences confirmed that there was greater rDLPFC activity in Responsibility compared with Diminished-Responsibility or No-Crime conditions ($R > DR, p = 0.002; R > NC, p = 0.0004$; paired t tests; see Figure 2B) and no difference between the Diminished-Responsibility and No-Crime conditions ($p = 0.19$). No effect of condition was found in the left DLPFC ($p > 0.2$ for all paired comparisons; see Experimental Procedures), and the rDLPFC was significantly more engaged than the left DLPFC in the Responsibility condition ($p = 0.04$, paired t test), suggesting that punishment-related prefrontal activation is confined to the right hemisphere. Bilateral anterior intraparietal sulcus (aIPS) demonstrated a pattern of responsibility-related activity that was similar to rDLPFC (Table S1 and Figure S1 available online, Supplemental Results), whereas the temporoparietal junction (TPJ) showed the reverse pattern, with more activity in the Diminished-Responsibility as compared with the Responsibility condition (Table S1, Figure 3, see below).

Greater rDLPFC activation in the Responsibility condition did not simply result from longer time on task; RTs to Responsibility scenarios were shorter than those of Diminished-Responsibility scenarios ($p = 0.005$, paired t test), and the effect of condition on rDLPFC activity was still significant when response time was used as a covariate in an analysis of covariance (ANCOVA, $F(1,37) = 10.15, p = 0.003$) or when response times were equated.
importantly, this early deactivation (‘‘dip’’) does not account for the peak activation results outlined above: the activation differences between conditions at the dip do not predict signal change [PSC] from baseline) around 8 s poststimulus onset. Importantly, this early deactivation (‘‘dip’’) does not account for the peak activation results outlined above: the activation differences between conditions at the dip do not predict corresponding activation differences at the peak (correlation of subjects’ activity differences between the Responsibility and Diminished-Responsibility conditions at the dip and at the peak: \( r = -0.19, p = 0.49; \) Figure S3; see Experimental Procedures). Furthermore, rDLPFC activity during nonpunished Diminished-Responsibility and No-Crime trials strongly differed at the dip \( (p = 0.008) \) but not at the peak \( (p = 0.97) \), indicating that peak activation differences are not simply carryover effects from differences during the dip.

fMRI Data: Punishment Magnitude

The finding that rDLPFC activity was higher when subjects decided to punish, in either Responsibility scenarios or in punished Diminished-Responsibility trials, raised the possibility that this brain region might track the amount of assessed punishment for a given criminal scenario. However, rDLPFC signal amplitude was not correlated with punishment ratings \( (p = -0.33, p = 0.15; \) Figure 2D) in the Responsibility condition. This finding suggests that the magnitude of punishment is not simply coded by a linear increase in rDLPFC activity.

Although rDLPFC activity was not proportional to punishment amount, a linear relationship between peak BOLD amplitude and punishment magnitude was found in a set of brain regions that have been extensively linked to social and affective processing. To isolate such effects, we compared Responsibility scenarios with high punishment ratings to those with low ratings (median split by scenario across subjects; see Experimental Procedures). The resulting SPM revealed activation in the right amygdala (peak Talairach coordinates 29, -7, -13; Figure 4; Figure S5) as well as in other brain regions commonly associated with social and affective processing (LeDoux, 2000; Phelps, 2006; Phillips et al., 2003; Price, 2005), including the posterior cingulate, temporal pole, dorsomedial and ventromedial prefrontal cortex, and inferior frontal gyrus (Table S2; Figures 4 and S5). The association between amygdala activity and punishment magnitude was further demonstrated by a strong correlation between amygdala BOLD signal and punishment ratings across Responsibility scenarios \( (p = 0.70, p = 0.001; \) Figure 4). However, punishment rating was not the only variable that correlated with amygdala function, as participants’ arousal ratings yielded a similar correlation with...
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amgmdala activity (p = 0.67, p = 0.001), and punishment and arousal ratings were themselves highly correlated (p = 0.98, p = 0.000001). Correlations between peak BOLD signal and punishment ratings (and between peak BOLD signal and arousal ratings) also held for a number of the other affective regions, including ventromedial prefrontal cortex and posterior cingulate cortex (Table S2; Figures S4 and S5), indicating that the relationship between affective processing and punishment involved a distributed neural circuit.

Although the correlation between amygdala activity and punishment scores could be interpreted as evidence for a role of emotional arousal in the assignment of deserved punishment, it is also possible that such activity simply reflected subjects’ emotional reaction to the graphic content of the scenarios rather than its involvement in the decision-making process per se. To avoid the potential arousal confound inherent to an examination of criminal scenarios that differ in graphic content (as was the case for our comparison of high versus low punishment scores within the Responsibility condition), we examined the relationship between punishment ratings and amygdala activity after controlling for the possible confounding effect of graphic arousal. Because Responsibility and Diminished-Responsibility scenarios were equated for graphic content and differed only by the presence of mitigating circumstances (see Experimental Procedures), the potentially confounding contribution of graphic arousal to amygdala activity in the Responsibility scenarios can be controlled for by subtracting amygdala activity in the Diminished-Responsibility scenarios from that in the corresponding Responsibility scenarios. If amygdala activity appertains to punishment magnitude rather than, or in addition to, emotional arousal related to the graphic content of the scenarios, it should still track punishment ratings even after subtracting out graphic content differences in the scenarios. To this end, we created, for each pair of Responsibility and Diminished-Responsibility scenarios, punishment rating difference scores (Responsibility minus Diminished-Responsibility) and assessed whether these scores were correlated with the corresponding difference scores for peak amygdala BOLD signal. That correlation was significant (p = 0.62, p = 0.001; Figure 4), indicating that the magnitude of amygdala BOLD signal difference between Responsibility and Diminished-Responsibility conditions for a given scenario predicted a corresponding change in punishment rating for that scenario. Similar correlations were found in posterior cingulate and ventromedial prefrontal cortex (Table S2). These findings suggest that activity within brain regions previously implicated in social and affective processing reflects third-party decisions about how much to punish, even after controlling for the potentially confounding arousal associated with the graphic content of the criminal scenarios.

DISCUSSION

The present findings suggest that the two fundamental components of third-party legal decision-making—determining responsibility and assigning an appropriate punishment magnitude—are not supported by a single neural system. In particular, the results reveal a key role for the right dorsolateral prefrontal cortex in third-party punishment. This brain region appears to be involved in deciding whether or not to punish based on an assessment of criminal responsibility. The only other brain region that demonstrated a comparable pattern of responsibility-related activity (R > DR, R > NC, DR = NC) to rDLPFC was the aIPS (Table S1, Figure S1, Supplemental Results). This parietal region has been associated with a number of diverse cognitive functions including general response selection (Gobel et al., 2004) and quantitative numerical comparisons (Dehaene et al., 1999, 2003; Feigenson et al., 2004), which may hint at a role for this area in associating a specific action (i.e. selecting a punishment outcome) with a given scenario.

Our results also implicate neural substrates for social and affective processing (including amygdala, medial prefrontal cortex, and posterior cingulate cortex) in third-party punishment, albeit in ways distinct from the rDLPFC. Specifically, while prefrontal activity was linked to a categorical aspect of legal...
decision-making (deciding whether or not to punish on the basis of criminal responsibility), the magnitude of assigned punishments for criminal transgressions parametrically modulated activity in affective brain regions, even after controlling for the potentially confounding arousal-related activity associated with the graphic content of the criminal scenarios. Our findings suggest that a set of brain regions (e.g., amygdala, medial prefrontal cortex, and posterior cingulated cortex) consistently linked to social and emotional processing (Adolphs, 2002; Amodio and Frith, 2006; Barrett et al., 2007; Lieberman, 2007; Phelps, 2006; Phillips et al., 2003; Zald, 2003) is associated with the amount of assigned punishment during legal decision-making. As such, these results accord well with prior work pointing to social and emotional influences on economic decision-making and moral reasoning (De Martino et al., 2006; Delgado et al., 2005; Koenigs and Tranel, 2007; Greene and Haidt, 2002; Greene et al., 2001, 2004; Haidt, 2001; Heekeren et al., 2003; Koenigs et al., 2007; Moll et al., 2002b, 2005), and provide preliminary neuroscientific support for a proposed role of emotions in legal decision-making (Arkush, 2008; Maroney, 2006). Our data concur with behavioral studies that have proposed a link between affect and punishment motivation in both second- and third-party contexts, and are consistent with the hypothesis that third-party sanctions are fueled by negative emotions toward norm violators (Darley and Pittman, 2003; Fehr and Fischbacher, 2004a, 2004b; Seymour et al., 2007). However, it must be acknowledged that the present conclusions rest exclusively on correlational data. Thus, additional research will be required to confidently determine the contributions of socio-affective brain regions to third-party punishment in the absence of any graphic arousal confound. In particular, it will be important in future experiments to fully dissociate the factors of crime severity and arousal by employing task conditions that manipulate arousal without affecting crime severity. Furthermore, future research should also focus on determining how these affective brain regions interact with DLPFC during third-party punishment decisions.

An additional concern in interpreting our findings, or any others based on simulated judgments, is whether they are relevant to real-world decision-making. After all, the punishment decisions made by our participants did not have direct, real-world consequences for real criminal defendants. Thus, it remains to be seen if our findings, generated by examining brain activation patterns during hypothetical judgments, will generalize to circumstances in which real punishments are made. However, there is some evidence suggesting that the hypothetical judgments made by our subjects may be a good proxy measure for real-world legal judgments. For example, postscan debriefing of our subjects indicated that their punishment assessments were implicitly legal, with lower numbers corresponding to lower prison sentences and higher numbers corresponding to higher prison sentences (see Table S3). Thus, participants appeared to adopt an internal punishment scale based on incarceration duration—a legal metric—when making their judgments, even in the absence of explicit instructions to do so. Further, we found that participants’ decisions about punishment amount for each of the crimes depicted in the Responsibility scenarios were strongly correlated with the recommended prison sentences for those crimes, according to the benchmark sentencing guidelines of North Carolina, a model state penal code ($\gamma = 0.8$, $p < .0001$; Figure S6; see Experimental Procedures). Thus, although our subjects were not literally applying a criminal statute to an accused individual, these data suggest that subjects’ punishment decisions were consistent with statutory legal reasoning. However, despite these suggestions, further empirical studies are required to confirm our supposition that neuroimaging studies of simulated third-party legal decision-making can validly model real-world legal reasoning.

Relative Contributions of TPJ and rDLPFC to Third-Party Punishment Decisions

The neural mechanisms of third-party punishment are undoubtedly complex, involving a dynamic regional interplay that unfolds in a temporally specific manner. In particular, the decision to punish a person for his blameworthy act is generally preceded by an evaluation of that person’s intention in committing that act (Alter et al., 2007; Carlsmith et al., 2002; Darley and Pittman, 2003; Darley and Shultz, 1990; Robinson and Darley, 1995; Robinson et al., 2007; Shultz et al., 1986). Such an evaluation ought therefore to activate brain regions that underlie the attribution of goals, desires, and beliefs to others, referred to as theory of mind (TOM) (Gallagher and Frith, 2003). One such region, the TPJ—a key node in the distributed TOM network (Decety and Lamm, 2007; Gallagher and Frith, 2003; Saxe and Kanwisher, 2003; Vollm et al., 2006)—might be predicted to serve this function during legal decision-making given recent evidence of its role in attributing mental beliefs in moral judgments (Young et al., 2007) and its involvement in dyadic economic exchange games (Rilling et al., 2004). Given this context, it is noteworthy that the TPJ was activated in all of our conditions (Figure 3). Furthermore, TPJ came online during the period when rDLPFC was deactivated (see Figure 2B), a result that is consistent with the suggestion that temporal-parietal cortex and DLPFC operate within largely distinct and at times functionally opposed networks (Fox et al., 2005). Given this proposed antagonistic response pattern in the TPJ and DLPFC, we speculate that the early rDLPFC deactivation may reflect a perspective-taking-based evaluation of the beliefs and intentions of the scenarios’ protagonist, which is followed by a robust rDLPFC activation as subjects go on to make a decision to punish based on assessed responsibility and blameworthiness. However, the conclusion that rDLPFC’s biphasic time course reflects an initial socio-evaluative process followed by a decisional process must be viewed as tentative because the present experiment did not constrain the temporal sequence of evaluative and decisional processes involved in this task.

Moral versus Legal Decision-Making

The results of the present neuroimaging study underscore the conceptual relationship between moral and legal decision-making. Indeed, the general involvement of both the prefrontal cortex and affective brain regions in legal reasoning is reminiscent of their roles in moral judgment (Greene et al., 2001, 2004). Specifically, moral decision-making studies have indicated that regions of lateral prefrontal cortex and inferior parietal lobe are preferentially involved in impersonal moral judgments, whereas socio-affective areas (e.g., amygdala, medial prefrontal cortex, and posterior cingulate cortex) may be primarily engaged during
personal moral decision-making (Greene et al., 2001, 2004). Thus, both legal and moral decision-making may rely on “cold” deliberate computations supported by the prefrontal cortex and “hot” emotional processes represented in socio-affective brain networks, although the extent to which these two decision-making processes rely on the same brain circuitry remains to be determined.

While these findings serve to highlight an important conceptual overlap between moral reasoning and legal reasoning in criminal contexts, they do not imply that third-party punishment decisions are reducible to moral judgment. Indeed, while legal decision-making may in most (but not all) criminal cases have an essential moral component, there are crucial distinctions between morality and law (Hart, 1958; Holmes, 1991; Posner, 1998). Perhaps the most critical distinguishing feature of legal decision-making, compared with moral decision-making, is the fundamental legal decision—assigning punishment for a crime—that is not a defining characteristic of moral judgment. Indeed, while moral decision-making studies to date have focused on assessing brain function during decisions about the moral rightness or wrongness of actions depicted in written scenarios, they have not specifically addressed the issue of punishment (Borg et al., 2006; Greene et al., 2001, 2004; Heekeren et al., 2003, 2005; Kedia et al., 2008; Luo et al., 2006; Moll et al., 2001, 2002a, 2002b; Young et al., 2007; Young and Saxe, 2008).

Neural Convergence of Second-Party and Third-Party Punishment Systems

The prefrontal cortex area activated in the present third-party legal decision-making study corresponds well to an area that is involved in the implementation of norm enforcement behavior in two-party economic exchanges (peak Talairach coordinates of 39, 37, 22 [x,y,z] for Knoch et al., 2006; Sanfey et al., 2003; versus 39, 38, 18 [x,y,z] for the present study), raising the possibility that rDLPFC serves a function common to both third-party legal and second-party economic decision-making. In this respect, it is noteworthy that this region of rDLPFC is recruited when participants decide whether or not to punish a partner by rejecting an unfair economic deal proposed by that partner (Sanfey et al., 2003); this result is analogous to our finding that rDLPFC is activated by the decision to punish the perpetrator of a criminal act. Furthermore, while disruptive magnetic stimulation of this region impairs the ability to punish economic norm violations in dyadic exchanges (Knoch et al., 2006; van't Wout et al., 2005), this manipulation has no effect on norm enforcement behavior when the unfair economic exchanges are randomly generated by a computer instead of a human agent (Knoch et al., 2006). This result accords well with our finding that rDLPFC was much less activated when the scenario protagonist was not criminally responsible for his behavior, and supports the notion that this prefrontal cortex area is primarily recruited when punishment can be assigned to a responsible agent (Knoch et al., 2006).

Finally, we still observed greater rDLPFC activity in the Responsibility condition (as compared with Diminished-Responsibility scenarios) when we restricted our analysis to scenarios that only contained physical harms (p < 0.005, paired t test), suggesting that the overlap of rDLPFC activity between studies of economic decision-making and the present examination of legal decision-making is not solely driven by scenarios describing economic transgressions.

The parallels between these previous findings and our current results lead us to suggest that the rDLPFC is strongly activated by the decision to punish norm violations based on an evaluation of the blameworthiness of the transgressor. This proposed function of rDLPFC appears to apply equally to situations where the motive for punishment is unfair behavior in a dyadic economic exchange or when responding to the violation of an institutionalized social norm in a disinterested third-party context. Of course, confirmation of this hypothesis will require further experimental evidence that legal and economic decision-making (and perhaps moral decision-making as well) rely on the same neural substrates. That said, this apparent overlap illustrates an important point: that the brain regions identified in our study are not specifically devoted to legal decision-making. Rather, a more parsimonious explanation is that third-party punishment decisions draw on elementary and domain-general computations supported by the rDLPFC. In particular, on the basis of the convergence between neural circuitry mediating second-party norm enforcement and impartial third-party punishment, we conjecture that our modern legal system may have evolved by building on preexisting cognitive mechanisms that support fairness-related behaviors in dyadic interactions. Though speculative and subject to experimental confirmation, this hypothesis is nevertheless consistent with the relatively recent development of state-administered law enforcement institutions, compared to the much longer existence of human cooperation (Richerson et al., 2003); for thousands of years before the advent of state-implemented norm compliance, humans relied on personal sanctions to enforce social norms (Fehr et al., 2002; Fehr and Gachter, 2002).

EXPERIMENTAL PROCEDURES

Subjects

Sixteen right-handed individuals (eight males, ages 18–42) with normal or corrected-to-normal vision participated for financial compensation. The Vanderbilt University Institutional Review Board approved the experimental protocol, and informed consent was obtained from each subject after they were briefed on the nature and possible consequences of the study. A brief psychological survey was also administered to exclude individuals who may react adversely to the content of the criminal scenarios. Exclusion criteria included history of psychiatric illness, being the victim of or having witnessed a violent crime (including sexual abuse), and having experienced any trauma involving injury or threat of injury to the subject or a close friend/family member.

Paradigm

In this experiment, subjects participated in a simulated third-party legal decision-making task in which they determined the appropriate level of punishment for the actions of a fictional protagonist described in short written scenarios. The principal goal of our study was to isolate the neural processes associated with the two fundamental processes of legal decision-making: deciding whether or not an accused individual is culpable for a given criminal act, and determining the appropriate punishment for that act (a parametric process based on the ordinal severity of a crime). Correspondingly, our design manipulated responsibility in a dichotomous fashion and crime severity in a continuous
fashion. Each participant viewed 50 scenarios (some inspired by prior behavioral studies of relative blameworthiness; Robinson and Darley, 1995; Robinson and Kurzban, 2007) depicting the actions of the protagonist named “John.” The 50 scenarios were subdivided into three sets (complete scenario list is available as Supplemental Experimental Procedures). In the Responsibility set (n = 20), the scenarios described John intentionally committing a criminal action ranging from simple theft to rape and murder. The Diminished-Responsibility set (n = 20) included similar actions comparable in gravity to those in the Responsibility set, but contained circumstances that would often legally excuse or justify the otherwise criminal behavior of the protagonist. The No-Crime set (n = 10) depicted John engaged in noncriminal actions that were otherwise structured similarly to the Responsibility and Diminished-Responsibility scenarios. The No-Crime scenarios were included to assist in interpreting activity differences between Responsibility and Diminished-Responsibility scenarios (e.g. Figure 2).

Two groups of 50 scenarios were constructed and their presentation counterbalanced across the 16 participants (8 subjects received group 1 scenarios, and 8 others received group 2 scenarios) and across gender (equal numbers of men and women received scenarios from each group). The Responsibility set of group 2 consisted of group 1 Diminished-Responsibility scenarios from which the mitigating circumstances had been excised, while the Diminished-Responsibility set of group 2 consisted of group 1 Responsibility scenarios with mitigating circumstances added. As a result, the Responsibility and Diminished-Responsibility scenarios were counterbalanced across subjects, and differed only by the presence of mitigating circumstances. Thus, exactly the same scenario premises were used in constructing the Responsibility and Non-Responsibility conditions. Finally, the No-Crime set was identical in both groups of scenarios, and all scenario sets were equated for word length.

Participants rated each scenario on a scale from 0–9, according to how much punishment they thought John deserved, with “0” indicating no punishment and “9” indicating extreme punishment. Punishment was defined for participants as “deserved penalty.” Participants were asked to consider each scenario (and thus, each “John”) independently of the others and were encouraged to use the full scale (0–9) for their ratings. In the scanner but prior to the functional scans, subjects were shown five practice scenarios that were designed to span the punishment scale. Scenarios were presented as white text (Times New Roman font) on a black background (14.2’ [width] × 9.9’ [height] of visual angle). Below each scenario, text reminded participants of the task instructions: “How much punishment do you think John deserves, on a scale from 0 to 9 where 0 = No punishment and 9 = Extreme punishment? By punishment, we mean deserved penalty.” Participants were instructed to make a response as soon as they had reached their decision.

Each trial began with the presentation of a scenario, which remained on-screen until participants made a button press response, or up to a maximum of 30 s. Participants then viewed a small white fixation square (0.25’ of visual angle) for 12–14 s (as stimulus onset was synchronized to scan acquisition [TR = 2 s], while stimulus offset was synchronized to subject response), which was followed by a larger fixation square (0.49’ of visual angle) for 2 s prior to the presentation of the next scenario. Ten scenarios (four Responsibility, four Diminished-Responsibility, and two No-Crime)—selected randomly without replacement from the fifty scenarios—were presented in each of the five fMRI runs. Scenario identity and order condition were randomized for each run. The duration of each fMRI run was variable, with a maximum length of 7.33 min. The experiment was programmed in Matlab (Mathworks, Natick MA) using the Psychophysics Toolbox extension (Brainard, 1997; Pelli, 1997) and was presented using a Pentium IV PC.

Following the scanning session, participants rated the same scenarios along scales of emotional arousal and valence. They first rated each of the 50 scenarios (presented in random order on a computer screen outside the scanner) on the basis of how emotionally aroused they felt following its presentation (0 = calm, 9 = extremely excited). They then rated each of the scenarios, presented again in random order, on the basis of how positive or negative they felt following its presentation (0 = extremely positive, 9 = extremely negative). In these sessions, subjects rated the same scenarios they viewed in the scanner. The valence data were highly correlated with arousal ratings, and multiple regression analysis demonstrated that they did not account for any additional variance in punishment ratings that is unaccounted for by the arousal data. Therefore, the valence data are not further discussed in this manuscript.

**Internal Scale Questionnaire**

In a postscan debriefing, participants were questioned about the internal scale of punishment they used during the scan. Specifically, participants were asked “what kind of punishment did you imagine?” for punishment scores of 1, 3, 5, and 9. There was strong agreement among participants about their internal scale of justice. While low punishment scores (1, 3) were generally associated with financial or social penalties, greater punishment scores (5, 8) included incarceration time, with higher scores associated with longer jail times and, at the extreme (9), life imprisonment or state execution.

**Relationship between Punishment Ratings and Legal Statutes**

To investigate the relationship between punishment ratings for Responsibility scenarios obtained in the present experiment and an existing, statutorily prescribed punishment for each of the crimes depicted in these scenarios, we coded each Responsibility scenario using the criminal law and criminal procedure statutes of the state of North Carolina. Among those states that have a sentencing statute, North Carolina’s is widely considered to be both comprehensive and exemplary (Stanley, 1996; Wright, 2002).

For each Responsibility scenario, we determined the crime or crimes (such as larceny, involuntary manslaughter, or murder) with which John might reasonably be charged under the criminal code of North Carolina (2005 General Statutes of North Carolina, Chapter 14). We then determined, for each crime, the authorized presumptive sentencing range (such as 58 to 73 months in prison), assuming no aggravating or mitigating factors that could, under the statute, increase or decrease the authorized sentencing range (2005 General Statutes of North Carolina, Chapter 15A, Article 81). We then calculated and assigned to each scenario the mean for this range, in months. As the distribution of sentence values was highly right-skewed, we log-transformed (natural log) to create a normal distribution of sentence values (we verified that nontransformed data produced similar correlations as transformed data). For scenarios with multiple crimes, the averages for each respective crime were summed (whether this summed value or simply the mean value for the most severe crime depicted in a given scenario was used in the correlation analysis did not significantly affect the results). Where the upper limit of the sentencing range was life in prison, it was coded as 29 years (which has been estimated as the average time likely to be served by lifers newly admitted in 1997) (Mauer et al., 2004). Similarly, where the upper limit of the sentencing range was death, it was also quantified as life in prison (29 years). The log-transformed mean sentences for each of the 20 scenarios were then correlated with the group-averaged punishment ratings for these scenarios.

**Statistical Analysis**

Mean punishment and arousal scores and RTs were calculated for each subject for each condition (Responsibility, Diminished-Responsibility, and No-Crime) and entered into a repeated-measures analysis of variance (ANOVA) using SPSS 15 (SPSS Inc., Chicago, IL) to determine main effects and interactions. Data from 16 subjects were used for all analyses. Punishment, arousal scores, and RTs were compared between conditions and post hoc tests were performed using Fisher’s Least Significant Difference (LSD) measure using an alpha level of 0.05. Two-tailed tests were used in all cases. For correlational analyses, data from Responsibility scenarios (n = 20) were averaged across all (n = 20) subjects. Examination of scatterplots for the correlation of rDLPFC signal and punishment suggested the presence of outliers. As nonparametric correlations tend to be more robust to outliers, we used Spearman’s p to measure correlations between rDLPFC signal, behavioral measures, and recommendation sentences. All correlations that were significant using Spearman’s p were also significant (p < 0.05) when we employed Pearson’s r.

**fMRI Data Acquisition**

High-resolution 2D and 3D anatomical images were acquired with conventional parameters on a 3T Philips Achieva scanner at the Vanderbilt Institute of Imaging Science. The visual display was presented on an LCD panel and back-projected onto a screen positioned at the front of the magnet bore. Subjects lay supine in the scanner and viewed the display on a mirror positioned above them. Stimulus presentation was synchronized to fMRI volume acquisition. Manual responses were recorded using two five-button keypads (one for each hand; Rowland Institute of Science, Cambridge, MA).
Functional (T2* weighted) images were acquired using a gradient-echo echoplanar imaging (EPI) pulse sequence with the following parameters: TR 2000 ms, TE 25 ms, flip angle 70°, FOV 220 x 220 mm, 128 x 128 matrix with 34 axial slices (3 mm, 0.3 mm gap) oriented parallel to the gyrus rectus. These image parameters produced good T2* signal across the brain except in ventromedial frontal cortex, where some signal dropout was evident in all subjects (Brodmann area 11).

Each of the 16 participants performed five fMRI runs, except for 2 partici- pants who could only complete four runs due to technical malfunctions.

fMRI Data Preprocessing
Image analysis was performed using Brain Voyager QX 1.4 (Brain Innovation, Maastricht, The Netherlands) with custom Matlab software (MathWorks, Natick, MA).

Prior to random effects analysis, images were preprocessed using 3D motion correction, slice timing correction, linear trend removal, and spatial smoothing with a 6 mm Gaussian kernel (full width at half maximum). Subjects’ functional data were coregistered with their T1-weighted anatomical volumes and transformed into standardized Talairach space.

Responsibility Analysis
This analysis was performed to isolate brain regions that were sensitive to responsibility during punishment assessment. Signal values for each fMRI run were transformed into Z-scores representing a change from the signal mean for that run and corrected for serial autocorrelations. Design matrices for each run were constructed by convolving a model hemodynamic response function (double gamma, consisting of a positive γ function and a small, negative γ function reflecting the BOLD undershoot – SPM2, http://www.filion.ucl.ac.uk/spm) with regressors specifying volumes acquired during the entire trial (stimulus onset to stimulus offset) for a given condition. These were entered into a general linear model (GLM) with separate regressors created for each condition per subject (random effects analysis). We then contrasted the beta-weights of regressors using a t test between conditions to create an SPM showing voxels that demonstrated significantly increased activation in the Responsibility condition as compared with the Diminished-Responsibility condition. Predictors for the No-Crime condition were weighted with a zero (i.e., not explicitly modeled). We applied a False-Discovery Rate (FDR) threshold of q < 0.05 (with [c(V) = ln(V)/E]) to correct for multiple comparisons. Only activations surviving this corrected threshold are reported.

Volumes of interest (VOIs) were created from the suprathreshold clusters isolated in the above SPM at the conservative FDR threshold. The boundary of these VOIs was drawn from SPMs thresholded using a less conservative implementation of FDR (< 0.05 FDR to correct for multiple comparisons). Using a conservative implementation of FDR (γ < 0.05) for each condition per subject (random effects analysis), we performed a median split for punishment scores. VOIs were then averaged across subjects for display purposes.

As subjects were instructed to make a response as soon as they had reached a decision about punishment amount, and in keeping with other neuroimaging studies of decision-making (Aron and Poldrack, 2006; Coricelli et al., 2005; Dux et al., 2006; Ivanoff et al., 2008; Rahm et al., 2006), decision-related activity should correspond to the portion of the time course that follows subjects’ response. Given that mean RTs hovered around 12 s (mean, SE for: Responsibility = 12.69 s, 0.46; Diminished-Responsibility = 13.76 s, 0.46; No-Crime = 11.12 s, 0.44; respectively) and accounting for a hemodynamic peak rise time of about 5 s poststimulus (Boynton et al., 1996; Friston et al., 1994; Heeger and Ress, 2002), perdecision activity should occur approximately 17 s after trial onset, which corresponds well with the time of peak hemodynamic response observed in rDLPFC (see Figure 2). We therefore used the peak hemodynamic response as a measure of decision-related activity. To determine condition effects on BOLD signal within a given brain region, we then contrasted each condition’s activation averaged across subjects by using paired t tests applied on these peak estimates. The peak was experimentally defined as the single volume with maximal signal change from baseline between volumes 1 and 13 (2-26 s poststimulus onset). However, we ascertained that the same results were obtained when the peak was defined using a narrower volume range of 14 to 22 s poststimulus (R > DR, p = 0.00070; R > NC, p = 0.00025; DR > NC, p = 0.19), or even when using a single volume 16 s poststimulus (R > DR, p = 0.00023; R > NC, p = 0.00027; DR > NC, p = 0.84). Thus, our rDLPFC peak activation results are insensitive to the temporal width of the analysis window.

Arousal- and Reaction-Time-Equated Analyses
To determine whether activation differences between the Responsibility and Diminished-Responsibility conditions were driven by punishment assessment rather than any differences in arousal, these two conditions were compared after equating for arousal ratings. This was accomplished by deleting the six trials with the highest arousal ratings from the Responsibility condition for each subject. Time courses were extracted and peak differences were compared as above.

We also determined whether RT differences between the Responsibility, Diminished-Responsibility, and No-Crime conditions affected the brain activation results by comparing these conditions after equating for response times. This was accomplished by deleting, for each subject, the trials with the highest RTs for Diminished-Responsibility scenarios and the trials with the lowest RTs for the No-Crime scenarios until the RTs across conditions (for each subject) were approximately equal (p > 0.1 for all paired t tests between conditions). In addition, we compared rDLPFC activation between Responsibility and Diminished-Responsibility scenarios controlling for RT by performing a GLM ANCOVA using the extracted rDLPFC BOLD signal and punishment RTs for each responsibility and Diminished-Responsibility scenario averaged across subjects.

Dissociation of Activation Peak and Deactivation Dip
To assess the relationship between early (~8 s) deactivation in the rDLPFC time course and later (~16 s) peak activation, we calculated peak and dip values for the Responsibility and Diminished-Responsibility conditions from each subject’s ERA. Peak and dip were defined as the volume with the maximal positive and maximal negative change from baseline, respectively. For each subject, we subtracted the Diminished-Responsibility peak value from the Responsibility peak value, and the Diminished-Responsibility dip value from the Responsibility dip value. Per-subject peak and dip difference values were then correlated via Spearman bivariate correlation in SPSS 15.

Laterality Analyses
To confirm the lateral specificity of Responsibility-related activation in rDLPFC, we extracted BOLD signal from the corresponding left rDLPFC VOI (i.e., “mirror” VOI, centered on Talairach coordinate -39, 37, 22). We performed a two-way ANOVA with “Condition” (Responsibility, Diminished-Responsibility, and No-Crime) and “Side” (Left and Right) as independent variables and BOLD signal as the dependent variable. Post hoc comparisons between conditions in each hemisphere, and between hemispheres for the Responsibility condition, were performed using paired t tests.

Punishment Rating Analysis
To identify brain regions that tracked the degree of punishment subjects assigned to a scenario, we performed a median split for punishment scores given during Responsibility scenarios. Based on the median punishment value for each scenario in the Responsibility condition across subjects, scenarios were separated into two groups, high and low. Design matrices and GLMs were constructed as above, with predictors for high and low scores for each subject specifying volumes acquired during Responsibility trials on which a high or low punishment score was given, respectively. We contrasted the beta-weights of these predictors using a t test between high and low punishments to create an SPM showing voxels that demonstrated significantly increased activation during Responsibility trials in which subjects gave high (at or above the median) punishments relative to Responsibility trials in which subjects gave low (below the median) punishments. We applied a threshold of q < 0.05 FDR to correct for multiple comparisons. Using a conservative implementation of the FDR correction technique (c(V) = ln(V) + E), we did not find significant activation differences. We report activations significant at FDR q < 0.05, using a less conservative implementation of FDR (c(V) = t). The differences between the two implementations relate to assumptions about the independence of tests being performed on the data; both are valid controls for multiple testing in functional imaging data (Genovese et al., 2002). VOIs were created as described for the Responsibility analysis. The extracted peak activation values were used for a correlation analysis between...
punishment rating and BOLD response. Specifically, for each of the 20 Responsibility scenarios, the peak amplitude of the group-averaged ERA was computed, and the resulting value was correlated with the corresponding group-averaged punishment rating for that scenario. These peak values were also used in the between-condition difference score analyses.

SUPPLEMENTAL DATA

The supplemental data for this article include Supplemental Results, six supplemental Figures, Experimental Scenarios, and three supplemental Tables and can be found at http://www.neuron.org/supplemental/S0896-6273(08)00889-1.

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REFERENCES

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Supplementary Results

The pattern of activity in bilateral anterior intraparietal sulcus (aIPS) resembled that seen in rDLPFC. In both left and right aIPS, activity during Responsibility trials was significantly greater than in Diminished-Responsibility (p = 0.006, right; p = 0.004, left) and No-Crime trials (p = 0.002, right; p = 0.0000008, left). aIPS activity did not differ significantly between Diminished-Responsibility and No-Crime trials (p = 0.6, right; p = 0.25, left). This pattern of results remained after equating for arousal differences between the Responsibility and Diminished-Responsibility conditions: Responsibility > Diminished-Responsibility (p = 0.002, right; p = 0.006, left), Responsibility > No-Crime (p = 0.0006, right; p = 0.003, left), Diminished-Responsibility = No-Crime (p = 0.58, right; p = 0.25, left). This pattern of results was also evident after equating for reaction time differences between conditions: Responsibility > Diminished-Responsibility (p = 0.006, right; p = 0.0003, left), Responsibility > No-Crime (p = 0.02, right; p = 0.0002), Diminished-Responsibility > No-Crime (p = 0.73, right; p = 0.57, left). As in rDLPFC, activity in “punished” Diminished-Responsibility trials was significantly greater than in “non-punished” Diminished-Responsibility trials (p = 0.01, right; p = 0.03, left) and activity in the “non-punished” Diminished-Responsibility trials was not significantly greater than in the No-Crime trials (p = 0.12, right; p = 0.55, left). Neither right or left
aIPS were significantly linearly correlated with punishment scores in the Responsibility condition (p = 0.17, right; p = 0.07, left).

Supplementary Figure 1.

**Supplementary Figure 1. Relationship between Responsibility and bilateral anterior intraparietal sulcus (aIPS) activity.** A) SPM displaying the right and left aIPS VOIs (rendered on a single subject T1-weighted image), based on the contrast of BOLD activity in the Responsibility condition compared to the Diminished-Responsibility condition, \( t(15) > 3.5, q < 0.05 \), random effects analysis. R = Right Hemisphere. B) BOLD activity time courses in right aIPS for the Responsibility, Diminished-Responsibility and No-Crime conditions. BOLD peak amplitude was significantly greater in the Responsibility condition compared to both the Diminished-Responsibility and No-Crime conditions (p = 0.006, p = 0.0002, respectively). C) BOLD activity time courses in left aIPS for the Responsibility, Diminished-Responsibility and No-Crime conditions. BOLD peak amplitude was significantly greater in the Responsibility condition compared to both the Diminished-Responsibility and No-Crime conditions (p = 0.004, p = 0.0000008, respectively). Peak was defined as the single TR with maximal signal change.
from baseline within the first 13 volumes after scenario presentation onset. *t*-tests were performed on these peak volumes, which were defined separately for each condition and each subject.

Supplementary Figure 2. Reaction time equated right DLPFC time course.

BOLD activity time course in right DLPFC after equating (per subject) for reaction time differences between conditions. Peak BOLD activity in right DLPFC was still significantly greater for Responsibility trials compared to Diminished-Responsibility (*p* = 0.006) and No-Crime trials (*p* = 0.002).
Supplementary Figure 3. Correlation of Peak (activation) and ‘Dip’ (deactivation) condition differences in right DLPFC. Scatterplot depicts the correlation of (per-subject) peak right DLPFC BOLD signal differences between Responsibility and Diminished-Responsibility scenarios and dip right DLPFC BOLD signal differences between Responsibility and Diminished-Responsibility scenarios. These variables were not significantly correlated (p = .69).
Supplementary Figure 4.
Supplementary Figure 4. Regional activity associated with punishment magnitude.

(A-C) SPMs displaying dorsomedial and ventromedial prefrontal cortex, posterior cingulate cortex, thalamus, midbrain, amygdala, right temporal pole, right and left lateral temporal cortex and left inferior frontal gyrus VOIs (rendered on a single subject T1-weighted image), based on the high punishment versus low punishment contrast in Responsibility scenarios, thresholded at $t(15) > 4.5$, $p < 0.0004$ (uncorrected) for visualization. All VOIs survive correction for multiple comparisons, $q$FDR) < 0.05; random-effects analysis. R = Right Hemisphere. (D-L) Scatterplots depict for each of these VOIs the relationship between peak BOLD signal and punishment magnitude for each Responsibility scenario.
Supplementary Figure 5. BOLD activity time courses for high punishment and low punishment Responsibility scenarios, based on the median split analysis of punishment scores. Amygdala (A), posterior cingulate (B), ventromedial prefrontal cortex (C), lateral temporal cortex (D) and cerebellum (E). Peak BOLD Responsibility and Responsibility-difference (Responsibility minus Diminished-Responsibility) responses in each of these VOIs are significantly correlated with punishment and punishment-difference scores, respectively.
Supplementary Figure 6. Relationship between punishment scores and sentence duration for Responsibility scenarios. Recommended mean sentence durations (natural log-transformed) for crimes depicted in the Responsibility condition were positively correlated with (subject-averaged) punishment scores for each Responsibility scenario ($p = 0.0001$).
Responsibility Scenarios

Set 1

1-20 = Responsibility
20-40 = Diminished-Responsibility
40-50 = No Crime

1) At the town bus station, John notices in a small gift shop a T-shirt of his favorite rock band. When no one appears to be looking in his direction, John takes a $15 T-shirt, places it in his coat and walks out, with no intention of paying for it.

2) John visits a fair, where a local company has masseuses offering “Free Massages” as an advertising tool. The person registering customers tells all clients that the limit is one massage per customer. John has a massage. Hours later, he returns using a false name, and gets another massage from a different masseuse.

3) John develops a plan to kill his 60-year-old invalid mother for the inheritance. He drags her to her bed, puts her in, and lights her oxygen mask with a cigarette, hoping to make it look like an accident. His mother screams as her clothes catch fire and she burns to death.

4) John is bored one week-end evening, as he is driving around the outskirts of his hometown. As John comes upon a farmer’s cornfield, he decides it would be a lot of fun to set the entire field on fire. He manages to get a large fire started and sticks around to watch the whole field burn.

5) John has been living with Heather for nearly six months. On Wednesday night, Heather tells him that it is over, and that she is breaking up with him. John pleads at first, but when that does not work, he gets very angry. John then gags Heather, firmly ties her to the bed, and rapes her.

6) John is a lifelong drug dealer who is always looking for ways to get more clients hooked on heroin. John knows of an acquaintance, Charlie, who is diabetic and regularly in need of insulin shots. One day, John manages to surreptitiously replace insulin with heroin for a single dose, hoping Charlie will become addicted to the drug.

7) John is parking his car in the parking lot of a local football stadium, where he plans to watch a game. In the car next to his, he sees a hat with his team logo in the back seat. Seeing that the door is unlocked, John opens the door, and takes the hat.

8) Angry after overhearing the derogatory remarks made by the coach towards his son during a little league soccer game, John approaches the coach, grabs him, knocks him down, then kicks him several times while he is on the ground. This knocks the man unconscious for several minutes and causes cuts that require five stitches.
9) John has just been fired by his boss, who gives John one week’s notice to leave the company. John decides to hurt her badly. At work the next day, when no one else is around, he picks up a letter opener from his desk, goes to his boss’s office, and stabs her. She later dies from the wound.

10) John plans to be a gangster for a Halloween office party. He buys suitable clothing, as well as a small loaded gun. The gun looks like a toy, and John plans to use it to kill a rival, and then claim it was an accident. He later shoots his rival, who dies of the injuries.

11) John has seen a nice set of golf clubs for sale at a local golf course. He does not have enough money to buy them. So John gets a friend to distract the store owner while he grabs the set of clubs and slips out through the back door of the store, and stashes the clubs in his car.

12) John approaches a home whose owners are absent, intending to take valuables. Although the back door is locked, the locking mechanism is not very secure. John pulls hard on the door, the lock gives way, and the door opens. John steps into the kitchen, sees a cell phone on the counter, and carries it away.

13) Two vicious pit bulls that John keeps for illegal dog fighting escaped and attacked a person who came to John's house. The police tell John he must destroy the dogs, which he agrees to do but does not intend to do. The next day, the dogs escape again and maul to death a delivery man.

14) One night John is bored. He approaches a neighbor’s home while she is away, and vandalizes the house and yard. First, he breaks five windows with rocks. Then he knocks over an expensive gas grill. Then he throws a bicycle into the pool. Finally, he breaks a child’s swing set before walking away.

15) While attending a football game of his favorite team, John becomes angry as he overhears a fan of the opposing team continuously make disparaging remarks about John's team. After the game, John sticks his face up in the man's face -- and head-butts him, causing a black-eye and a gash that requires two stitches.

16) A record store patron, standing next to John, is wearing a cap that mocks John's political party. John follows the man from the store, confronts him, and then slaps him in the face hard, causing him to stumble. The man's face develops a black and yellow bruise that persists for one week.

17) One day at a local park, John approaches a man walking a dog and demands money from him. When the man refuses to turn over his money, John punches the man in the face, breaking his jaw and causing several cuts that each require stitches. John then runs off without getting any money.
18) John kidnaps an 8 year-old girl for ransom, rapes her, then records the child's screams as he burns her with a cigarette lighter, sending the recording to her parents to induce them to pay his ransom demand. Even though they pay as directed, John strangles the child to death to avoid leaving a witness.

19) John is baby-sitting a neighbor’s eight-month old son, who he takes on an errand. John thinks it may be too hot to safely leave the toddler in the car, but he decides to leave him there anyway as he will be returning soon. However, John strikes a conversation with a shop-owner, forgetting about the toddler, who passes out and dies.

20) John is a cab driver in town. On Saturday, a seemingly unsophisticated customer enters the cab. John, who knows that his electronic meter is working fine, pretends it is broken, so that he can overcharge the customer by $5.00. The customer is unaware of this, and pays the amount John requests.

21) John attends a party hosted by a hypnotist. Under hypnosis, John does uncharacteristic and comical deeds, until something goes wrong. Attempting to demonstrate that hypnotized people are harmless, the hypnotist tells John to strike a nearby woman. John grabs a lamp and hits the woman, who dies of the injuries. When brought out of hypnosis, John has no recollection.

22) John visits a local bookstore, carrying a large shopping bag with goods from another store. While the store clerk is preoccupied with inventory, another customer, hoping to use John unwittingly in a theft, sneaks a book into John’s shopping bag. Without realizing what has happened, John walks out without paying for the book.

23) John has a license to hunt deer with his licensed rifle. One day, he sees a deer, takes aim, and shoots – missing the deer but killing a distant hunter. The deceased hunter had not complied with important state safety regulations. In particular, he was not wearing “hunter orange” to distinguish himself from target animals.

24) John’s friend Gregory is training for a boxing match. He has been working on his abdominal muscles, and asks John to hit him there repeatedly to help Gregory “toughen up.” John repeatedly punches Gregory in the stomach until Gregory asks him to stop, at which point John stops. Gregory suffers bruises and one broken rib.

25) John fills his new prescription at the pharmacy. Unbeknownst to John and his doctors, this prescription interacts with John’s other medications to induce severe acute psychoses. That day, John comes home, pours gasoline around his house and sets it on fire while the wife he adores is inside. She consequently dies.

26) John has recently experienced delusions. He had checked himself into a mental hospital to get treatment, but he was released yesterday due to a clerical error. Today, he wanders into a clothing store, and walks out with twelve children’s shorts without paying. The proprietor does not see him, and there are no children among John’s friends or family.
27) A brain tumor is causing increasingly erratic, violent, and callous behavior in John. Soon, he develops an uncontrollable urge to kill. John abducts a boy, puts a broomstick in the boy’s rectum, and lashes him with a whip until he dies. When the tumor is later found and removed, John’s behavior returns to normal.

28) John is at the batting cage, down in the park. John is unaware that a man has thoughtlessly entered the cage and is walking up behind him. On John’s next back-swing, he hits the man behind him in the head, breaking the man’s nose and giving him cuts that require several stitches to close.

29) John is in the crowded elevator of a local apartment building, on his way to visit a friend who lives there. He suddenly has an epileptic seizure, with uncontrollable muscle convulsions. He has never had these before. A man unknown to John, who is standing next to him, is hit in the arm and bruised.

30) John purchases a snake from a pet store owner who mistakenly believes and explains that the snake is non-poisonous. John has no reason to think otherwise, although the snake is actually poisonous. It bites one of John’s guests as she reaches into the tank to pick the snake up. The guest dies from the venom.

31) Hiking in the backcountry, John and his boy scouts get lost. Making matters substantially worse, one of the boys steps on a rattlesnake and is bitten. The troop then stumbles upon an abandoned house, which John sets on fire to draw rescuers. The plan works and the kid is saved, but the house is destroyed.

32) John owns an ice cream truck, which he drives to the city park. One customer gives John a $50.00 bill for a $2.00 ice cream. John intends to give correct change, but he miscounts and returns $5.00 less than the customer was owed. Neither John nor the customer notices the discrepancy.

33) One morning, John’s house was burglarized. One of the items taken was a distinctive framed picture of the Jamaican Olympic Bobsled Team. Later that day, John is walking in the neighborhood and notices his framed picture in the back seat of an unlocked car. He opens the door and takes the picture.

34) John is walking home one night. A man wearing a ski-mask jumps from the bushes, holding a knife and demanding John’s wallet. After John presents his wallet, the man tries to stab John. In the scuffle, John succeeds in knocking out the thug, who is hospitalized with a head injury and cuts needing five stitches.

35) John attends a local concert at which the sponsor has a table clearly labeled “Free CDs,” to promote the musical band. A small separate sign stating “Limit: One per Customer” had fallen to the ground behind the table, and John has not seen it. He takes two CDs and leaves.
36) John is at home, baby-sitting a neighbor’s two-year old daughter. Local laws require a fence around pools to prevent infant drownings. John had previously arranged for professional installation of extra-strong fencing exceeding local requirements. Unbeknownst to John, a section of the fence is defective. The girl later pushes through that section, falls into the pool, and drowns.

37) A dishonest cop keeps pressuring John for “protection money”, meaning he can keep John from “getting hurt” so long as John keeps paying him. When John runs out of cash, the cop orders him to buy alcohol at the liquor store, and then resell it to minors for a $1,000 profit. John does so.

38) At a party, and unbeknownst to John, the host slips John some illegal drugs as a joke. John starts hallucinating wildly. He goes into the street and attacks an empty car with rocks, bottles, bricks, his fists, and his feet. The car is considerably damaged. The next day, he has no recollection of the evening.

39) While kart racing, John suddenly notices a stalled kart racer ahead of him. John attempts to veer around the kart, but due to a mechanical failure, the wheel locks and he crashes into the other kart. That kart’s driver suffers a large bump on the head and needs two stitches to close an associated cut.

40) John is walking with his daughter when a well-known and frequently violent drug-dealer confronts them. Showing a gun, he instructs John to steal from the house across the street, “or else you won’t ever get to walk your little daughter again.” John, believing him, immediately breaks a window, takes two brass candlesticks, and turns them over

41) One day, John picks up some allergy medicine at his local pharmacy. The label on the medication clearly states: “Store in a cool, dry place.” John is aware of what the label says, and knows his bathroom can be hot and humid. But he stores his medicine in the bathroom anyway.

42) John goes to the house of his best friend, Gus, to borrow a screwdriver. Gus says: “Please take and keep this one. I have many more than I need.” John says “Thanks, but I only need it this once.” Although John plans to return the screwdriver, he later forgets and ends up keeping it.

43) John buys a variety of different kinds of flowers and bushes, and plants them in his backyard. For several weeks, John cares for them diligently and waters them regularly. Eventually John enters a busy period at work, during which he forgets about the plants. By the time he pays attention again, they have all died.

44) Early one morning, John arrives at his place of work, and realizes that he has left his key at home. He goes around the building exterior, trying to find a door that may be unlocked. He tries all of them, unsuccessfully. A co-worker finally arrives, and lets John in with her own key.
45) John has dinner one night at a local restaurant he has not visited before. Although the food arrives promptly and tastes quite good, John finds the service wholly unacceptable. At various times, the waiter was rude, neglectful, confrontational, and even verbally abusive. When leaving, John pays for his meal, but leaves no tip.

46) A friend invited John to dinner. John is on his way but is stuck in traffic caused by an accident. He has no opportunity to detour, and no way to contact his friend to let him know he’ll be late. When John arrives 2 hours late, the meal has unavoidably dried out and is ruined.

47) The manual to John’s new car states: “The oil must be changed no less frequently than every 4,000 miles.” John reads the manual and is aware of what it says. However, John drives the car for 4,023 miles before taking it to a service station for the car’s first oil change.

48) John and his best friend have played golf together for more than ten years. They used to be evenly matched, but recently John’s friend has consistently outplayed him. Growing frustrated, John responded by taking private golf lessons from the local pro. The next time John played against his friend, he soundly beat him.

49) John is out walking when he sees a five-dollar bill on the sidewalk. John looks around to see if there is anyone who might have dropped it. Because it is very early in the morning, there is no one around. John picks up the money, and puts it in his pocket, intending to keep it.

50) On Halloween, John hangs a scary-looking plastic monster from the creepiest tree in the front yard of his home. Most of his evening’s visitors seem to enjoy it. However, several of the youngest children out trick-or-treating with their parents are so scared that their parents have to take them straight home.
1) John owns an ice cream truck, which he drives to the city park. One customer gives John a $50.00 bill for a $2.00 ice cream. Hoping that the customer will not bother counting her change, John provides $5.00 less in change than the customer is owed. The customer walks away without noticing the discrepancy.

2) After careful planning, John abducts a boy for a “snuff” video (a video recording, to be sold on the black market, of someone being killed in a gruesome way). On camera, John binds the boy, puts a broomstick in his rectum, and lashes him with a whip until he dies. John then sells the recording.

3) John goes down to the park at night, carrying a baseball bat. He demands money from a man walking a dog. When the man refuses, John hits the man with the bat, breaking his nose and giving him cuts that require several stitches to close. John then runs off without getting any money.

4) John is at home, baby-sitting a neighbor’s two-year old daughter. Local laws require fencing around pools to prevent infant drownings. John knew but ignored the requirement. John leaves his back door open for air circulation while watching television and drinking beer. The girl crawls out and drowns in the pool, where John finds her forty minutes later.

5) One night John is bored. He decides it would be fun to vandalize a car. He finds one on the street in the neighborhood and attacks it. First, he kicks it and pelts it with rocks. Then he breaks bottles on it. Then he hurls bricks, and the like. The car is considerably damaged.

6) One day, John is in a crowded elevator of a local apartment building, and sees a man wearing a T-shirt with a political slogan John finds offensive. John pursues the man off the elevator, abuses him verbally, then pushes him hard against the wall. The man’s arm is bruised by the encounter.

7) One night, John decides to steal some brass candlesticks that he sees through the window of a house whose owners appear to be away. John tries several windows but finds them all locked. He finally breaks one, and climbs into the house. He then takes the candlesticks and leaves the house.

8) John and his friend have longed for the expensive leather jackets on sale at a local clothing store. One day, they decide to act. While the friend distracts the owner in the front of the shop, John quickly gathers up four leather jackets. John then slips out the back of the store and stashes the jackets in his car.
9) On Saturday, John attends a local concert at which the sponsor has a table clearly labeled “Free CDs,” to promote a new musical band. John sees and understands a small separate sign stating “Limit: One per Customer.” When the attendant is looking the other way, John takes two CDs and leaves.

10) John is bored one week-end evening, and decides it would be fun to start a fire in the empty room of an old abandoned building in his home town. John hopes that the whole building will go up in flames. John lights the fire and the entire building burns, as he watches from a distance.

11) While kart racing, John notices Jake, a long-time rival, to his right. Remembering old grudges, John tries to cause Jake to crash, veers his vehicle toward Jake’s. Jake’s car consequently slams into a wall. Jake suffers a large bump on his head and needs two stitches to close a cut he received in the crash.

12) John, who lives at home with his father, decides to kill him for the insurance money. After convincing his father to help with some electrical work in the attic, John arranges for him to be electrocuted. His father survives the electrocution, but he is hospitalized for three days with injuries caused by the electrical shock.

13) John knows very well that it is illegal to keep a poisonous snake at home. But he does so anyway, because deadly snakes are cool, and laws are dumb. One night, the snake escapes, travels to the guest room, and bites John’s house-guest. Shortly thereafter, the guest dies from the poison.

14) John, wearing a dark suit and ski-mask, jumps up from behind some bushes and confronts a man on his way home from work. John, holding a knife, demands that the man turn over his wallet. After getting the wallet, John knocks the man unconscious, and the man later requires 5 stitches.

15) John develops a plan to kill his ex-wife so that he no longer has to pay alimony. One day, John enters her home, pretending to be a burglar. He stabs his ex-wife repeatedly. Hoping to cover his tracks, he then pours gasoline around her house and sets it on fire. She dies in the blaze.

16) After work, John hosts a party at his house that Lucy attends. During the evening, and unbeknownst to Lucy, John keeps spiking Lucy's lemonade with vodka, hoping that she will become drunk and willingly have sex with him. After numerous drinks, Lucy gets alcohol poisoning and has to be rushed to the hospital.

17) Things have been going badly for John at work. He feels persecuted by one person, in particular. John follows her for several days, learning her routes between work and home. Intending to hurt her badly, John comes from behind in an alley and strikes her over the head with a club. The woman later dies from her wounds.
18) John has a passionate affair with the girlfriend of an acquaintance, and has been plotting to get rid of him. John invites the acquaintance to a deer hunt, planning to shoot and kill him under circumstances that could make it look like an accident. Finding his opportunity, he shoots and kills the man.

19) John visits a local bookstore, carrying a large shopping bag that contains goods from another store. John sees a book he would like to have. When no one appears to be looking his way, John quickly slips a book into his shopping bag. John leaves the store without paying for that book.

20) John is walking one morning and sees a framed picture of the Jamaican Olympic Bobsled Team in the back of a car. John returns to the car later, and checks to see if the doors are locked. Finding one of the doors unlocked, he opens the door and takes the picture with him.

21) At the bus station, John notices in a small gift shop a T–shirt of his favorite rock band. While the store clerk is preoccupied with inventory, another customer, hoping to use John unwittingly in a theft, sneaks the T-Shirt into John’s coat pocket. John walks out without paying for the T-shirt.

22) John’s undetected brain tumor causes him to believe he hears angel voices. He thinks the angels have identified a demon-girl who could bring about a global apocalypse. Following the angels’ exact instructions, John kidnaps and ritualistically rapes, tortures, and strangles the girl. When the tumor is later found and removed, John no longer hears voices.

23) John has recently experienced delusions. He had checked himself into a mental hospital to get treatment, but he was released yesterday due to a clerical error. Today, he wanders into a golf store, picks up a bag of clubs, and walks out with them without paying. The proprietor does not see him, and John does not play golf.

24) John is successfully hypnotized by his inexperienced psychiatrist, who is trying to help John control his feelings by first visualizing himself committing violent acts, and then visualizing himself overcoming his desire to do them. While visualizing, John grabs a letter-opener and stabs the psychiatrist, who later dies from the wound. Later, John has no recollection of the event.

25) John plans to be a gangster for a Halloween office party. His friend offered to lend John a gangster costume, complete with a gun, and John accepted. John assumes the gun is a harmless toy, but it is actually real and loaded. John playfully shoots it at a co-worker, who then dies of the injuries.

26) John is a cab driver in town. On Saturday, a seemingly unsophisticated customer enters the cab. John is unaware that his electronic meter is malfunctioning. Reading from the meter, and assuming that the meter is accurate, John in fact overcharges the customer by $5.00. Both he and the customer are unaware.
27) John owns two dogs of a very popular breed that is widely considered to be extremely docile and harmless. One day a neighborhood bully sneaks into John’s yard while John is away, and repeatedly shoots the dogs with a BB-gun. Irritated, the dogs rush the man, who stumbles and dies of bite wounds.

28) While at a local record store, John has a sudden epileptic seizure with uncontrollable muscle convulsions. He has never had these before. A customer in the store, who had been standing next to John, is hit and hurt. The man’s face develops a black and yellow bruise that persists for one week.

29) While attending a football game, John realizes he’s forgotten his team hat. He returns to the parking lot, and mistakes a car of the same make, model, and color for his own. The car is unlocked and also has a similar hat in the back seat. John takes it, believing it is his.

30) At a party, and unbeknownst to John, the host slips him some illegal drugs as a joke. John starts hallucinating wildly. He goes next door, breaks windows with rocks, knocks over a gas grill, throws a bicycle into the pool, and breaks a child’s swing set. The next day, he has no recollection of this.

31) John is baby-sitting a neighbor’s eight-month old son. With that neighbor’s prior consent, John takes the child on an errand. John gets out of the car, closes his door, and prepares to retrieve the child. Although John has never fainted before, he suddenly faints and falls. By the time he awakens, the child has died from heat buildup in the car.

32) Unbeknownst to John and his doctors, his new prescription interacts with his other medications to induce severe acute psychoses. During that interaction, John returns home to his 60-year old invalid mother, who he has always adored. John lights her oxygen mask with a cigarette, and watches as his mother catches fire, screams, and burns to death.

33) John is attending a football game. When his team scores a touchdown, John stands up to celebrate, as do the other fans in front. At that instant, the person behind John bends forward to pick up a soda. John strikes heads with the man behind, who gets a black-eye and a gash requiring two stitches.

34) John is out driving one evening and is the first to see a forest fire raging toward a town of 10,000 people. John intentionally sets fire to a farmer’s cornfield, which is located right in between the fire and the town. The burned field then serves as a firebreak, and the fire does not reach the town.

35) While cheering for his son at a soccer match, John is attacked by a parent of a child on the opposing team, who knocks John down and jumps on top of him. John struggles, but eventually hits the man hard enough to knock him unconscious for several minutes and leave cuts requiring five stitches.
36) One night, John sleepwalks to the home of an absent neighbor. John pulls on the back door, the lock gives way, and the door opens. John enters the kitchen, takes a cell phone from the counter, and carries it away. The next morning, John has no recollection of the event, or the origin of the phone.

37) John is home one night, watching TV, when his girlfriend sneaks up to the house, intending to scare him. Wearing a trench coat and a hat, she slips in through the back door, stomping heavily toward the living room. Frightened, John leaps up and stabs her with a kitchen knife. Her injured arm requires surgery.

38) John visits a fair, where a local company has masseuses offering “Free Massages” as an advertising tool. The person registering customers forgets to tell John that the limit is one massage per customer. John remains unaware of the policy. John has a massage. Hours later, he returns and gets another massage from a different masseuse.

39) John is practicing his martial arts moves at a local park. Unbeknownst to John, an acquaintance walking a dog comes behind him to surprise John. As John shifts to his next move, he accidentally punches the man in the face, breaking the man’s jaw and causing several cuts that each require stitches.

40) John and his wife have been using prescription fertility drugs, in an effort to have a baby. Unbeknownst to either of them, their houseguest placed a syringe of heroin in the refrigerator, near the fertility drugs. That night, John mistakenly injects his wife with heroin, instead of the fertility drug.

41) On Halloween, John hangs a scary-looking plastic monster from the creepiest tree in the front yard of his home. Most of his evening’s visitors seem to enjoy it. However, several of the youngest children out trick-or-treating with their parents are so scared that their parents have to take them straight home.

42) Early one morning, John arrives at his place of work, and realizes that he has left his key at home. He goes around the building exterior, trying to find a door that may be unlocked. He tries all of them, unsuccessfully. A co-worker finally arrives, and lets John in with her own key.

43) John buys a variety of different kinds of flowers and bushes, and plants them in his backyard. For several weeks, John cares for them diligently and waters them regularly. Eventually John enters a busy period at work, during which he forgets about the plants. By the time he pays attention again, they have all died.

44) John is out walking when he sees a five-dollar bill on the sidewalk. John looks around to see if there is anyone who might have dropped it. Because it is very early in the morning, there is no one around. John picks up the money, and puts it in his pocket, intending to keep it.
45) A friend invited John to dinner. John is on his way but is stuck in traffic caused by an accident. He has no opportunity to detour, and no way to contact his friend to let him know he’ll be late. When John arrives 2 hours late, the meal has unavoidably dried out and is ruined.

46) John has dinner one night at local restaurant he has not visited before. Although the food arrives promptly and tastes quite good, John finds the service wholly unacceptable. At various times, the waiter was rude, neglectful, confrontational, and even verbally abusive. When leaving, John pays for his meal, but leaves no tip.

47) John and his best friend have played golf together for more than ten years. They used to be evenly matched, but recently John’s friend has consistently outplayed him. Growing frustrated, John responded by taking private golf lessons from the local pro. The next time John played against his friend, he soundly beat him.

48) The manual to John’s new car states: “The oil must be changed no less frequently than every 4,000 miles.” John reads the manual and is aware of what it says. However, John drives the car for 4,023 miles before taking it to a service station for the car’s first oil change.

49) One day, John picks up some allergy medicine at his local pharmacy. The label on the medication clearly states: “Store in a cool, dry place.” John is aware of what the label says, and knows his bathroom can be hot and humid. But he stores his medicine in the bathroom anyway.

50) John goes to the house of his best friend, Gus, to borrow a screwdriver. Gus says: “Please take and keep this one. I have many more than I need.” John says “Thanks, but I only need it this once.” Although John plans to return the screwdriver, he later forgets and ends up keeping it.
### Supplementary Table 1. Anatomical location and Statistical Assessment of Activation for VOIs identified from Responsibility SPMs, p<.05 (corrected).

<table>
<thead>
<tr>
<th>Contrast</th>
<th>Region</th>
<th>Talairach Coordinates (X, Y, Z)</th>
<th>t value (peak)</th>
<th>p value (peak)</th>
<th>Arousal-equated p value (peak)</th>
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<tbody>
<tr>
<td>Responsibility &gt; Diminished-Responsibility (t &gt; 5.7)</td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>R. Anterior Intraparietal Sulcus</td>
<td>35,-44,47</td>
<td>11.1</td>
<td>0.006</td>
<td>0.6</td>
<td>R&gt;DR 0.002 0.02 0.58</td>
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<tr>
<td>L. Anterior Intraparietal Sulcus</td>
<td>-37,-45,53</td>
<td>8.7</td>
<td>0.004</td>
<td>0.25</td>
<td>DR&gt;NC 0.00000008 0.006</td>
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<td>R. Dorsolateral Prefrontal Cortex</td>
<td>39,38,18</td>
<td>5.8</td>
<td>0.0009</td>
<td>0.33</td>
<td>R&gt;NC 0.001 0.005 0.14</td>
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<tr>
<td>R. Cerebellum</td>
<td>23,-45,-21</td>
<td>9.8</td>
<td>0.004</td>
<td>0.45</td>
<td>R&gt;DR 0.02 0.07 0.45</td>
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<tr>
<td>L. Motor Cortex</td>
<td>-42,-24,46</td>
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<td>6E-05</td>
<td>0.12</td>
<td>DR&gt;NC 0.01 0.007 0.19</td>
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<td>R. Precuneus</td>
<td>12,-62,35</td>
<td>6.4</td>
<td>0.06</td>
<td>0.04</td>
<td>NC&gt;R 0.002 0.04 0.04</td>
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<td>L. Precuneus</td>
<td>-16,-67,34</td>
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<td>0.18</td>
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<td>DR&gt;NC 0.3 0.16 0.95</td>
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<td>Dorsal Anterior Cingulate Cortex</td>
<td>-2,1,42</td>
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<td>0.005</td>
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<td>Diminished-Responsibility &gt; Responsibility (t &gt; 5.7)</td>
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<td>R. Temporoparietal Junction</td>
<td>55,-53,27</td>
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<td>L. Temporoparietal Junction</td>
<td>-48,-57,25</td>
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<td>0.001</td>
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<td>DR&gt;NC 0.006 0.002 0.44</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>NC&gt;R 0.008 0.007</td>
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<tr>
<td>Contrast</td>
<td>Region</td>
<td>Talairach Coordinates (X, Y, Z)</td>
<td>t value (peak)</td>
<td>Correlation with Punishment</td>
<td>Correlation with Arousal</td>
</tr>
<tr>
<td>--------------------------</td>
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<tr>
<td>High &gt; Low Punishment ( (t &gt; 4.7) )</td>
<td><strong>Ventromedial Prefrontal Cortex</strong></td>
<td>-3,49,24</td>
<td>9.4</td>
<td>( \rho = .52, p &lt; .02 )</td>
<td>( \rho = .57, p &lt; .01 )</td>
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<td></td>
<td><strong>Dorsomedial Prefrontal Cortex</strong></td>
<td>-3,33,46</td>
<td>5.6</td>
<td>( \rho = .02, p &lt; .93 )</td>
<td>( \rho = .07, p &lt; .77 )</td>
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<td></td>
<td><strong>R. Amygdala</strong></td>
<td>29, -7, -13</td>
<td>6</td>
<td>( \rho = .67, p &lt; .001 )</td>
<td>( \rho = .67, p &lt; .001 )</td>
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<tr>
<td></td>
<td><strong>R. Temporal Pole</strong></td>
<td>43, 21, 12</td>
<td>6.6</td>
<td>( \rho = .14, p &lt; .55 )</td>
<td>( \rho = .24, p &lt; .31 )</td>
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<td></td>
<td><strong>R. Lateral Temporal Cortex</strong></td>
<td>51, 1, -12</td>
<td>6.5</td>
<td>( \rho = .54, p &lt; .02 )</td>
<td>( \rho = .55, p &lt; .01 )</td>
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<td></td>
<td><strong>L. Lateral Temporal Cortex</strong></td>
<td>-54, -3, -15</td>
<td>6.6</td>
<td>( \rho = .54, p &lt; .02 )</td>
<td>( \rho = .55, p &lt; .01 )</td>
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<td></td>
<td><strong>Midbrain</strong></td>
<td>-6, -31, -1</td>
<td>5.6</td>
<td>( \rho = .34, p &lt; .14 )</td>
<td>( \rho = .32, p &lt; .17 )</td>
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<tr>
<td></td>
<td><strong>Posterior Cingulate</strong></td>
<td>-3, -48, 31</td>
<td>7.2</td>
<td>( \rho = .75, p &lt; .0001 )</td>
<td>( \rho = .75, p &lt; .0001 )</td>
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<td></td>
<td><strong>Thalamus</strong></td>
<td>-2, -5, 7</td>
<td>5.8</td>
<td>( \rho = .42, p &lt; .06 )</td>
<td>( \rho = .41, p &lt; .08 )</td>
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<tr>
<td></td>
<td><strong>L. Inferior Frontal Gyrus</strong></td>
<td>-42, 25, -1</td>
<td>5.7</td>
<td>( \rho = .49, p &lt; .03 )</td>
<td>( \rho = .48, p &lt; .03 )</td>
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<tr>
<td></td>
<td><strong>R. Cerebellum</strong></td>
<td>29, -41, -20</td>
<td>6.7</td>
<td>( \rho = .51, p &lt; .03 )</td>
<td>( \rho = .50, p &lt; .02 )</td>
</tr>
</tbody>
</table>

| Low > High Punishment \( (t > 4.7) \) | **R. Motor Cortex**           | 46, -18, 51                     | 7.1            | \( \rho = -.61, p < .005 \) | \( \rho = -.61, p < .004 \) | \( \rho = -.47, p < .04 \)                  |
### Supplementary Table 3. Internal Punishment Scale

<table>
<thead>
<tr>
<th>Participant</th>
<th>Punishment Rating</th>
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<tr>
<td>AA</td>
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<tr>
<td>BB</td>
<td>Punishment Rating</td>
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<tr>
<td>CC</td>
<td>Punishment Rating</td>
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<tr>
<td>DD</td>
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<tr>
<td>EE</td>
<td>Punishment Rating</td>
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<td>FF</td>
<td>Punishment Rating</td>
</tr>
<tr>
<td>GG</td>
<td>Punishment Rating</td>
</tr>
<tr>
<td>HH</td>
<td>Punishment Rating</td>
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<tr>
<td>II</td>
<td>Punishment Rating</td>
</tr>
<tr>
<td>JJ</td>
<td>Punishment Rating</td>
</tr>
<tr>
<td>KK</td>
<td>Punishment Rating</td>
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<tr>
<td>LL</td>
<td>Punishment Rating</td>
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<tr>
<td>MM</td>
<td>Punishment Rating</td>
</tr>
<tr>
<td>NN</td>
<td>Punishment Rating</td>
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<tr>
<td>OO</td>
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<table>
<thead>
<tr>
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<th>3</th>
<th>5</th>
<th>8</th>
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<tbody>
<tr>
<td>AA</td>
<td>Small Fine</td>
<td>Large Fine</td>
<td>Short Jail Sentence</td>
<td>Long Jail Sentence</td>
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<tr>
<td>BB</td>
<td>Small fine</td>
<td>Short Jail Sentence</td>
<td>Long Jail Sentence</td>
<td>&quot;Humane Execution&quot;</td>
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<tr>
<td>CC</td>
<td>Social Penalty</td>
<td>Public Ostracism</td>
<td>Short Jail Sentence</td>
<td>Long Jail Sentence</td>
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<tr>
<td>DD</td>
<td>Victim Compensation</td>
<td>Community Service</td>
<td>Short Jail Sentence</td>
<td>Long Jail Sentence</td>
</tr>
<tr>
<td>EE</td>
<td>Victim Compensation</td>
<td>Short Jail Sentence</td>
<td>Medium Jail Sentence</td>
<td>Long Jail Sentence</td>
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<tr>
<td>FF</td>
<td>Victim Compensation</td>
<td>Small Fine</td>
<td>Large Fine</td>
<td>Jail Sentence</td>
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<tr>
<td>GG</td>
<td>Victim Compensation</td>
<td>Probation</td>
<td>Short Jail Sentence</td>
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<tr>
<td>HH</td>
<td>Probation</td>
<td>Short Jail Sentence</td>
<td>Medium Jail Sentence</td>
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<tr>
<td>II</td>
<td>Fine</td>
<td>Short Jail Sentence</td>
<td>Medium Jail Sentence</td>
<td>Long Jail Sentence</td>
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<td>JJ</td>
<td>None</td>
<td>Social Ostracism</td>
<td>Jail (NOS)</td>
<td>Life Imprisonment</td>
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<td>KK</td>
<td>Social Penalty</td>
<td>Community Service/Fine</td>
<td>Fine/Short Jail Sentence</td>
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<tr>
<td>LL</td>
<td>Social Penalty</td>
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<td>MM</td>
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<td>NN</td>
<td>None</td>
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<td>OO</td>
<td>Social Penalty</td>
<td>Community Service</td>
<td>Large Fine</td>
<td>Life Imprisonment</td>
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NOS = relative sentence not otherwise specified