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Behavioral and autonomic reactivity to moral dilemmas in frontotemporal dementia versus Alzheimer's disease

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ABSTRACT
The personal/impersonal distinction of moral decision-making postulates intuitive emotional responses from medial frontal activity and rational evaluation from lateral frontal activity. This model can be analyzed in behavioral variant frontotemporal dementia (bvFTD), a disorder characterized by impaired emotional intuitions, ventromedial prefrontal cortex (vmPFC) involvement, and relative sparing of lateral frontal regions. Moral dilemmas were presented to 10 bvFTD, 11 Alzheimer's disease (AD), and 9 healthy control (HC) participants while recording skin conductance responses, a measure of emotional arousal. We evaluated their personal versus impersonal conflict, subjective discomfort, and adherence to social norms. Replicating prior work, bvFTD participants were more willing to harm in the personal, but not the impersonal, dilemma compared to AD and HC groups. BvFTD participants had lower arousal and less of an increase in conflict on the personal versus the impersonal dilemma, in contrast to increased arousal and conflict for the AD and HC groups. Furthermore, bvFTD participants verbalized less discomfort, a correlate of low adherence to social norms. These findings support impaired emotional reactions to moral dilemmas in bvFTD and vmPFC lesions and the personal/impersonal model. It suggests a reversion to utilitarian-like considerations when emotional intuition is impaired in the brain.

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Introduction

Philosophers have long debated the role of emotions in morality and whether moral requirements are grounded strictly in standards of rationality and volitional capacities to reason. Immanuel Kant and moral rationalists proposed that moral principles are revealed through reason alone. In contrast, moral sense theorists such as David Hume argued that morality is essentially determined by emotions such as empathy. The argument for emotion and intuition in moral decision-making has recently garnered support from the study of brain-injured patients with damage to the frontal lobes who have select impairments of emotional, intuitive moral judgment (Koenigs et al., 2007; Mendez & Shapira, 2009; Moretto, Làdavas, Mattioli, & di Pellegrino, 2010).

Moral dilemmas and moral decision-making

Investigators have relied on moral dilemmas to investigate the role of emotion in moral decision-making. They interpret such dilemmas as articulating moral conflict between an emotion-driven intuition to not harm others and reasoned considerations for a greater good (e.g., saving more lives). In the much-used version of Foot's "trolley problem" (Foot, 1967), participants contemplate a scenario where a runaway trolley is hurtling toward five railway workers. The workers will be crushed to death unless the participant pulls a switch directing the trolley onto a sidetrack, where it will kill one worker. The "footbridge" variant (Thomson, 1976) introduces an emotional "personal" factor because the five can be saved only if the participant physically pushes a bystander off a footbridge into the path of the oncoming trolley, halting its travel but killing the bystander.

Studies using large-scale survey data show that between 80% and 90% of normal respondents would choose to kill one person to save five lives when the victim is harmed as a by-product of the "impersonal" act of pulling a switch. Yet only 10–35% would choose to kill one person when it requires intentional personal

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contact, as in the footbridge case (Greene, 2013; Hauser, Cushman, Young, Jin, & Mikhail, 2007). In the trolley "switch" version, the duty to "do no harm" is more easily overcome because the harm is an incidental by-product of the impersonal act of pulling a switch. However, in the "footbridge" version, this duty is more difficult to overcome because the harm involves direct personal interaction with the potential victim (Greene, Nystrom, Engell, Darley, & Cohen, 2004).

Using these dilemmas, Greene et al. proposed a dual-process model in which separate emotion-based and reason-based subsystems correspond to deontological and utilitarian processes, respectively (Greene, Sommerville, Nystrom, Darley, & Cohen, 2001). When contemplating moral dilemmas, these subsystems compete and generate conflict between emotional intuitions on one hand (e.g., "Don't kill!"), and deliberative reasoning on the other (e.g., "Five lives saved are better than one life lost"). Studies suggest that the emotional intuitions are mediated by medial frontal regions, particularly the ventromedial prefrontal cortex (vmPFC), while cognitive reasoning is mediated in dorsolateral frontal regions (Ciaramelli, Muccioli, Làdavas, & di Pellegrino, 2007; Greene & Haidt, 2002; Greene et al., 2004, 2001; Mendez, 2009; Moll & de Oliveira-Souza, 2007; Moretto et al., 2010; Young & Koenigs, 2007). Functional MRI investigations of patients with focal vmPFC lesions reveal a strong association between impairments in emotion processing and anticipatory emotional reactions, and impairments in personal moral judgments (Ciaramelli et al., 2007; Young & Koenigs, 2007). In contrast, impersonal moral dilemmas produce increased activity in dorsolateral prefrontal cortex (DLPFC) and parietal areas associated with deliberate cognitive processing and working memory (Drevets & Raichle, 1998; Greene et al., 2001).

There are, however, challenges to this dual-process model of competing subsystems. Investigators question the respective roles of emotion and reason and whether they represent deontological and utilitarian decisions, respectively (Borg, Hynes, Van Horn, Grafton, & Sinnott-Armstrong, 2006; Kahane, 2015; Kahane, Everett, Earp, Farias, & Savulescu, 2015; Manfrinati, Lotto, Sarlo, Palomba, & Rumiati, 2013). Others question the immediate versus delayed aspects of deontological emotional processing compared to rational processing (Christensen, Flexas, Calabrese, Gut, & Gomila, 2014). Alternate mechanisms, such as impaired Theory of Mind (ToM), rather than emotional responses, could account for decreased personal responses to moral vignettes in neurological disorders that affect the vmPFC (Gleichgerrcht, Torralva, Roca, Pose, & Manes, 2011), and research into the salience network (SN) and default mode network (DMN) challenge the simple vmPFC-DLPFC neuroanatomy of the dual-process model of moral reasoning (Chiong et al., 2013). Finally, in psychopaths and patients with behavioral variant frontotemporal dementia (bvFTD), vmPFC dysfunction may be associated with reasoned "utilitarian-like" responses despite the presence of self-centered, unempathic, and even sociopathic behavior (Liljegren et al., 2015; Rankin, Kramer, & Miller, 2005; Rosas & Koenigs, 2014). Although the dual-process model has been challenged, the personal/impersonal distinction continues to be a useful tool to distinguish performance on moral dilemmas.

BvFTD and moral emotions

BvFTD, a neurodegenerative disease of the medial frontal and anterior temporal lobes, is a critical model for analyzing the personal/impersonal distinction in moral decision-making and judgment (Neary et al., 1998; Piguet, Hornberger, Mioshi, & Hodges, 2011; Rascovsky et al., 2011). Core behavioral features of bvFTD include disinhibition, social disengagement, and indifference to others (Neary et al., 1998; Rascovsky et al., 2011). Studies on bvFTD patients show deficits in empathy (Eslinger, Moore, Anderson, & Grossman, 2011; Rankin et al., 2005), and patients with bvFTD are prone to violations of social norms and antisocial or criminal acts (Diehl-Schmid, Perneczky, Koch, Nedopil, & Kurz, 2013; Liljegren et al., 2015; Mendez, Chen, Shapira, & Miller, 2005; Miller, Darby, Benson, Cummings, & Miller, 1997). Patients with bvFTD also exhibit impairments in emotional reactivity to personal moral dilemmas, responding with a dispassionate approach lacking in emotional concern for others (Carr et al., 2015; Ciaramelli et al., 2007; Mendez, Anderson, & Shapira, 2005).

The present study

This was the first study to investigate verbal responses and emotional arousal to moral dilemmas during the process of moral decision-making in patients with bvFTD compared to patients with Alzheimer's disease (AD) and healthy controls (HCs). Behavioral measures on willingness to act, amount of conflict and level of discomfort with their decisions, and their insensitivity to social norm violations were coupled with autonomic nervous system measures of emotional arousal such as skin conductance, a measure of sympathetic reactivity (Figner & Murphy, 2011; Navarrete, McDonald, Mott, & Asher, 2012). We expected to replicate previous findings of impaired personal moral decision-making in patients with bvFTD compared to patients with AD and HCs. In addition, skin conductance studies have correlated changes in physiological arousal with activity in the vmPFC, an area especially affected by bvFTD (Zhang et al., 2014, 2012). As such, we predicted that the bvFTD patients would choose to commit personally harmful action with less moral conflict, subjective discomfort, and emotional arousal compared to patients with AD and HCs. Together, these findings support the personal/impersonal distinction in moral decision-making and suggest that emotions such as empathy have a role in guiding moral decisions.

Methods

Participants

We enrolled 10 bvFTD and 11 AD participants from the UCLA Neurobehavior Clinic, after ethics board approval from the UCLA Medical Institutional Review Board, Office for Protection of Research Subjects (http://www.oprs.ucla.edu), and written informed consent from patient participant and caregiver. The participants were mild–moderately impaired dementia patients living with their families, who underwent clinical, neuropsychological, and neuroimaging assessments. These participants were part of a larger recruitment for psychophysiological studies, and we excluded patients on β-blocker medications and those with potentially confounding medical, neurological, or psychiatric disorders. An additional nine healthy HCs were recruited from volunteers in the community. The study controlled for group differences in medications except for acetylcholinesterase inhibitors or memantine among AD participants. None of the participants were taking psychoactive medications.

The 10 participants with bvFTD presented with progressive behavioral changes consistent with bvFTD, that is, disinhibition and social norm violations, apathy and inertia, loss of empathy, stereotypical behaviors, dietary or food preferences, and dysexecutive neuropsychological scores. A clinical diagnosis of probable bvFTD was based on International Consensus Criteria for bvFTD and included the frontal–anterior temporal predominant changes on neuroimaging (Rascovsky et al., 2011).

In order to control for nonspecific dementia variables, the study enrolled 11 participants with clinically probable AD as a comparison group. The AD participants met the National Institute of Aging-Alzheimer Association criteria for clinically probable AD (McKhann et al., 2011). They were early onset (<65 years) in order to match with the bvFTD age group. Both the bvFTD and AD groups underwent general measures of dementia severity, including the Mini-Mental State Examination (MMSE) (Folstein, Folstein, & McHugh, 1975).

Procedures

Moral dilemmas

Participants were presented with computerized versions of moral dilemmas that probed the necessity for harmful action of an impersonal nature (pull switch) or personal nature (push man off footbridge). Scenario content was created using SuperLab Pro 4.0 software and appeared on a video monitor with text synchronized with line drawings and audio narration so as to facilitate comprehension among dementia patients. Experimenters remotely monitored participants and stimuli from an adjoining room, allowing researchers to assess alertness and attentiveness to the stimuli.

Moral dilemmas were presented in two separate sections, each consisting of four parts: (1) inter-stimulus baseline recording; (2) participant instructions; (3) presentation of either (3a) impersonal switch dilemma or (3b) personal footbridge dilemma; (4) verbal responses to either (4a) impersonal switch dilemma or (4b) personal footbridge dilemma.

(1) Preceding each dilemma was a baseline period of 22 s in which participants were requested by text on the screen: "*Please relax and remain still*." Baseline skin conductance readings were recorded.
(2) Instructions immediately followed on a subsequent screen of approximately 6 s with text and concurrent audio: "*Listen to the story. Then answer the questions at the end*."
(3) After the instructions were given, one of two dilemmas was presented:
    a. The impersonal trolley "switch" version consisted of a sequence of seven screens with synchronized illustrations, text and audio narration. The duration of presentation was approximately 55 s. This version involves the impersonal use of a switch to divert the trolley to a side track.
    b. The personal "footbridge" version also consisted of a sequence of seven screens with synchronized illustrations, text and audio narration. The duration of presentation was approximately 55 s. This version involves direct personal interaction to push a large man onto the tracks to stop the trolley.
(4) Following each dilemma, participants were asked two questions, each projected on the computer screen and linked to the corresponding dilemma.

a. Questions following impersonal "switch" dilemma:
   (i) Question #1: "*YOU MUST DECIDE WHAT TO DO. If you don't do anything, the trolley will kill 5 people on the main track. But if you pull the switch it will kill 1 person on the side track." "Would you pull the switch? Yes or No?"* As a measure of moral conflict, the participants' responses were recorded and timed from the initial screen presentation of the question to the point of initial verbal completion of a "yes" or "no" response.
   (ii) Question #2: "*How do you feel about your decision?"* As a measure of discomfort with their decisions, two raters coded these verbal responses for expressions of a negative or positive emotional nature on a three-point scale: 0 = absent, 1 = somewhat present, 2 = clearly present. The participants were allowed unrestricted time to consider and respond.
b. Questions following personal "footbridge" dilemma:
   (i) Question #1: *"YOU MUST DECIDE WHAT TO DO. If you don't do anything, the trolley will kill 5 people on the main track. But if you push the very large man off the footbridge, he will be killed. Would you push the man? Yes or No?"* Responses were recorded and timed as before.
   (ii) Question #2: This procedure was identical to that for the first dilemma.

Psychophysiology assessment

Autonomic nervous system activity was measured using Biopac hardware (MP150W) recorded with Biopac software (Acqknowledge v4.1). Autonomic arousal was measured as phasic skin conductance amplitude (microsiemens) with a minimal response criterion of 0.02 μS for inclusion in the analyses. Sensors attached to the first and third fingers of each participant's nondominant hand and were continuously recorded during the presentation and contemplation of dilemmas. Raw values were log-transformed to minimize the influence of large values. To correct for individual differences in general autonomic reactivity, values recorded during dilemmas were divided by the mean skin conductance response (SCR) at baseline for each participant. These values were then standardized by *z*-score to simplify interpretation. Thus, autonomic nervous system activity was operationalized as the transformed skin conductance values during the mental processing of dilemma content relative to one's baseline at rest.

Sociomoral behavioral and social norm measures

The participants completed two inventories previously used to assess their moral knowledge and tendency to social norm violations, the Moral Behavior Inventory (MBI) and the Social Norms Questionnaire (SNQ) (Mendez & Shapira, 2009; Possin et al., 2013). These brief instruments have been used to assess the sociomoral impairments of patients with bvFTD.

Statistical analysis

Each statistical analysis was conducted using SPSS v22 along the following lines: (1) demographic statistics for each group were compared using χ^2 and *t*-test for categorical and continuous variables, respectively. Group responses on sociomoral inventories were compared using one-way analysis of covariance (ANOVA). (2) Group verbal responses to the dilemmas were dichotomized (1 = "yes") and compared using a χ^2 procedure, as were the emotional content ratings. Differences in response times in seconds across groups were examined using a series of a mixed plot ANOVA with additional repeated measures and one-way ANOVAs to explore *post hoc* differences. (3) For our analysis of emotional arousal, a regression model was used with SCRs as the dependent variable (M = 0.023, SD = 0.084), and dilemma type (switch/footbridge) and group (bvFTD/AD/control) as categorical independent variables (dummy-coded 0/1 with switch condition and control group as reference categories). Standard errors were calculated to conservatively reflect degrees of freedom based on sample size (N = 30), not the number of outcomes. Finally, Pearson correlations examined the relationship between the sociomoral scales, verbal responses, and psychophysiological outcome measures.

Results

Group characteristics

There were no significant group differences in age, education (years), or sex distribution (see Table 1). However, the AD group was significantly more impaired on the MMSE compared to the HC group (but not compared to those with bvFTD). There were no group differences on the MBI, but the SNQ was significant worse for the bvFTD participants compared to those with AD.

Table 1. Characteristics of the bvFTD, AD, and HC groups.

	bvFTD	AD	HC	$F(2, 30)$; p-value
Age	62.40 (11.51)	61.36 (5.70)	53.88 (9.51)	2.93; n.s.
Education	16.00 (1.89)	16.55 (1.86)	16.14 (1.68)	0.27; n.s.
Sex (M, F)	4,7	3,9	4,9	n.s.
MMSE	27.40 (2.41)	25.30 (3.30)*	29.5 (0.9)*	8.94; 0.001
MBI	71.57 (24.58)	72.89 (8.78)	71.09 (12.78)	0.04; n.s.
SNQ	15.67 (3.39)*	20.78 (2.05)*	18.73 (3.63)	7.12; 0.003

Means and standard deviations except for gender. AD = Alzheimer's disease; bvFTD = behavioral variant frontotemporal dementia; HC = healthy control; MBI = Moral Behaviors Inventory; MMSE = Mini-Mental State Examination; SNQ = Social Norms Questionnaire. *Post hoc significant differences: MMSE AD vs. HC; SNQ bvFTD vs. AD.

Verbal responses

Question #1: *Would you pull the switch? Yes or no?* For the impersonal switch dilemma, all of the bvFTD (100%) participants and most of the AD (73%) participants and HCs (89%) said "yes" to pulling the switch despite harming the man on the alternate track (n.s.) (see Figure 1). In contrast, on the personal footbridge dilemma, the majority of bvFTD (90%) participants said "yes" to pushing the man off the footbridge, but less than half of both the AD (45%) and HC (45%) groups would do so ($\chi^2 = 5.81$; $p = 0.01$; significant differences bvFTD vs. AD and HC at $p < 0.03$).

According to a mixed ANOVA (split plot), the rate of responding ("conflict time") differed by group and condition (Wilks' $\lambda = 0.72$, $F(2, 27) = 5.18$, $p = 0.012$). Across conditions, responses were significantly faster for

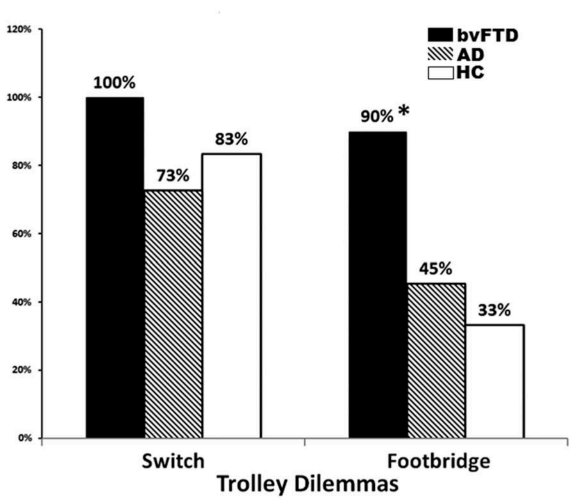

Figure 1. Question 1 verbal response: percent with yes answers. There were no significant group differences on the trolley switch (impersonal) dilemma, but there were significant group differences on the footbridge (personal) dilemma ($\chi^2 = 5.81$; $p = 0.01$). *bvFTD group was significantly different from both AD and HC groups ($p < 0.03$). AD = Alzheimer's disease; bvFTD = behavioral variant frontotemporal dementia; HC = healthy control.

Table 2. Sample self-reports to "*How do you feel about your decision?*".

	bvFTD	AD	HC
Trolley	"Ok"	"I don't feel good about it at all"	"Terrible"
	"Good"	"Sad, but you try to do your best"	"It was a difficult decision…"
	"I don't know"	"Lousy"	"Horrible"
	"I feel good"	"I'm still at a loss for whether I did the right thing"	"Both options absolutely suck, so I feel crappy"
Bridge	"That's very true "	"Not good. I just don't know"	"Not good. It's a no win situation"
	"I feel good about it"	"As I said, I couldn't live with myself if I did that"	"I feel terrible about the decision…"
	"Ok"	"Devastated"	" Awful! Awful!…"
	"I feel it was a wise decision"	"Not good, but I don't know what to do"	"…I don't feel good about it at all, for anybody to die"

AD = Alzheimer's disease; bvFTD = behavioral variant frontotemporal dementia; HC = healthy control.

bvFTD than AD and HC groups ($\eta^2 = 0.23$, $F(2, 29) = 4.06$, $p = 0.029$). Across groups, responses were significantly slower for the footbridge compared to the switch condition (Wilks' $\lambda = 0.72$, $F(1, 27) = 0.27$, $p = 0.003$). Most notably, both AD participants (Wilks' $\lambda = 0.55$, $F(1, 10) = 7.52$, $p = 0.023$) and HCs (Wilks' $\lambda = 0.64$, $F(1, 10) = 5.50$, $p = 0.041$) were significantly slower on the footbridge compared to the trolley switch version, but the bvFTD participants did not show a significant response time difference between dilemmas (Wilks' $\lambda = 0.92$, $F(1, 8) = 0.23$, $p = 0.430$).

Question #2: *How do you feel about your decision?* Actual responses for the bvFTD differed in their positive or negative content from those of the AD and HC groups (see Table 2). Two raters coded these responses as positive or negative with high inter-rater reliability ($\kappa = 0.62$ and 0.75, respectively). Across dilemmas, the groups differed significantly by the strength of their emotional expression in both positive emotions ($\eta^2 = 0.28$, $F(2, 28) = 5.03$, $p = 0.014$) and negative emotions ($\eta^2 = 0.39$, $F(2, 28) = 8.30$, $p = 0.002$) (see Table 3). The bvFTD participants had significantly more positive emotions compared to both AD ($p = 0.011$) and HC ($p = 0.010$) groups. The bvFTD participants also had significantly fewer negative emotions compared to HCs ($p < 0.001$) and approached significantly fewer with the AD group ($p = 0.053$). There were no differences in these verbal responses between the two dilemmas.

Psychophysiology

The results of the analysis showed a significant main effect for dilemma type ($\beta = 0.08$, $F(1, 29) = 5.80$, $p = 0.023$); the participants were more aroused when mentally processing the personal footbridge dilemma

Table 3. Raters evaluations of valence of expressed emotions.

	bvFTD Mean (SD)	AD Mean (SD)	HC Mean (SD)	p-Value	κ
Expresses positive emotion	0.63 (0.81)[a,b]	0.06 (0.16)[a]	0.03 (0.08)[b]	0.014	0.62
Expresses negative emotion	0.31 (0.43)[c,d]	0.79 (0.56)[c]	1.33 (0.60)[d]	0.002	0.75

Coding: 0 = absent, 1 = somewhat present, 2 = strongly present.
[a]bvFTD vs. AD (p = 0.002).
[b]bvFTD vs. HC (p = 0.001).
[c]bvFTD vs. AD (p = 0.053).
[d]bvFTD vs. HC (p = 0.004).
AD = Alzheimer's disease; bvFTD = behavioral variant frontotemporal dementia; HC = healthy control.

Table 4. Regression table: regression model for predictors of autonomic arousal.

	B	SE	t	p-Value	95% CI	
Dilemma						
Personal	0.079	0.033	2.410	0.023	0.012	0.147
Condition						
AD	0.015	0.020	0.750	0.460	−0.026	0.055
bvFTD	0.023	0.022	1.040	0.306	−0.022	0.069
Dilemma × condition						
Footbridge × AD	0.014	0.044	0.320	0.748	−0.076	0.104
Footbridge × bvFTD	−0.119	0.047	−2.540	0.017	−0.214	−0.023
Model constant						
–	−0.012	0.013	−0.970	0.342	−0.038	0.014

N = 30, $F(5, 29)$ = 3.52, R^2 = 0.29.
AD = Alzheimer's disease; bvFTD = behavioral variant frontotemporal dementia.

(M = 0.001, SD = 0.05), relative to when processing the impersonal switch version (M = 0.046, SD = 0.11). However, this main effect was qualified by a significant interaction between dilemma type and participant group; the pattern of autonomic arousal among bvFTD participants deviated from the pattern found among the HCs (β = −0.12, $F(1, 29)$ = 6.47, p = 0.017), and that found among AD participants (β = −0.13, $F(1, 29)$ = 9.07, p = 0.005). In fact, the pattern of arousal was reversed among bvFTD participants (see Figure 2). The AD participants, in contrast, were not significantly different than HCs ($F(1, 29) < 1$). A regression model confirmed that the interaction of bvFTD × footbridge dilemma significantly predicts decreased autonomic reactivity on SCRs (see Table 4).

Correlations

Further individual correlations were obtained between the two sociomoral behavioral scales, the MBI and SNQ,

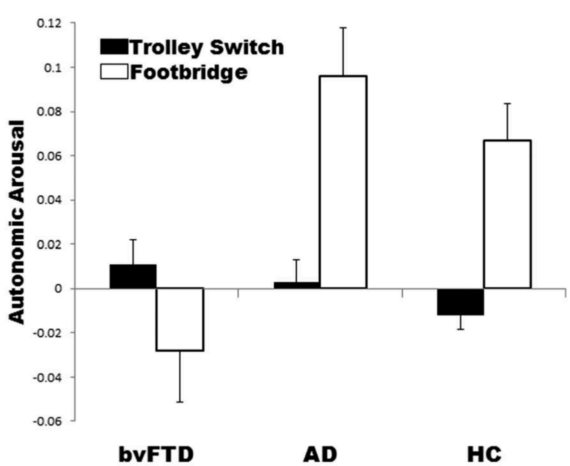

Figure 2. Autonomic nervous system arousal by moral dilemma type and condition. Arousal indicates skin conductance values (standardized) recorded during the mental processing of the trolley switch (impersonal) and footbridge (personal) moral dilemmas. Error bars represent standard deviations.

the quantitative verbal responses (response times and positive–negative comments), and the psychophysiological outcome measure. There were no significant correlations except across groups with the SNQ. The SNQ results negatively correlated with the expression of positive emotions on both the trolley switch (r = −0.627; p = 0.012) and the footbridge (r = −0.585; p = 0.003) dilemmas.

Discussion

This study investigated the personal/impersonal distinction in moral decision-making among participants with bvFTD compared to those with AD and HC. Consistent with previous findings, the bvFTD participants were more willing to push a man to his death in order to stop a trolley from killing five other people, than AD participants and HC. Importantly, we extended this replication by analyzing the connections between dilemma outcomes and emotional responses, as measured via verbal self-reports and autonomic nervous system responses. We found that bvFTD participants showed more positive emotional responses when responding to moral dilemmas, whereas the AD and HC groups expressed distress and an unwillingness to cause direct harm to another person. In contrast to the other groups, the bvFTD group showed decreased conflict (measured by time to respond) and emotional arousal (measured by SCRs) at the prospect of committing harmful actions that involve direct personal interaction. These findings indicate that bvFTD patients have dysfunction of the emotional processes that guide moral behavior. Furthermore, it suggests that, in the absence of these emotions, they quickly and without hesitation resort to a "morality" that values the saving of more lives, despite their tendency to selfishness and social norm violations.

This study replicates earlier findings in bvFTD, a disorder that involves the vmPFC, with further analyses of autonomic and verbal responses and comparison to another dementia group as a secondary control. Other studies, using novel techniques such as virtual reality presentations of the trolley dilemmas, note increased emotional reactivity to the footbridge version compared to the switch version in normal participants (Navarrete et al., 2012). Despite the association of bvFTD with apathy, none of the bvFTD patients expressed indifference to either dilemma; yet, they did not show discomfort or concomitant sympathetic reactivity to killing someone to save five lives. In this study, the bvFTD patients did not experience the immediate automatic visceral emotional response of aversion to the idea of physically pushing someone off a footbridge to their death, suggesting that their decreased emotional arousal is associated with a lack of emotional empathy

BvFTD damages precisely the prefrontal-paralimbic areas that mediate emotional engagement and negative emotional appraisals to moral violations. The vmPFC seems to be critical for generating judgments of right and wrong when resolution of moral conflict requires social emotions (Damasio, 1994; Greene et al., 2004; Haidt, 2001; Koenigs et al., 2007; Mendez, Anderson, et al., 2005; Moretto et al., 2010). In a study of patients with lesions of the vmPFC, Moretto and colleagues found lower SCR to personal moral judgments when compared to controls, consistent with the facilitation of personal moral violations when there is decreased emotional arousal (Moretto et al., 2010). The current study does not ask for moral judgments, but, rather, evaluates moral-based decision-making, which may not involve precisely the same neural and/or psychological mechanisms (Tassy, Deruelle, Mancini, Leistedt, & Wicker, 2013; Tassy, Oullier, Mancini, & Wicker, 2013). Nevertheless, diseases or lesions that involve the right vmPFC may impair emotional responsiveness in situations that involve decision-making regarding personal harm, such that patients with these focal injuries fail to have the emotional arousal that typically deters decisions to harm others (Mendez, 2009).

Among the most important emotions for guiding moral decision-making and judgment is emotional *empathy* – the capacity for congruent feelings with what another person is experiencing. Emotional empathy, which is distinct from cognitive empathy and perspective taking, guides many moral evaluations and reactions to moral transgressions, and is impaired in bvFTD (Decety, 2011; Decety & Jackson, 2004; Decety, Michalska, & Kinzler, 2012; Rankin et al., 2005). In a study of multiple components of empathy, investigators found bvFTD deficits in moral aspects dependent on emotion recognition as well as ToM (Baez et al., 2014). Empathy may guide moral capacities by integrating ToM with information about others' thoughts, preferences, and consequences in the context of moral judgment (Decety & Howard, 2013). In bvFTD, reduced empathic concern, particularly for negative experiences, may be critical in facilitating their responses to personal moral dilemmas (Gleichgerrcht et al., 2013; Oliver et al., 2015). Emotional empathy involves more than empathic concern or emotional ToM, but includes emotional sharing; further research is needed to clearly disentangle the impact of subdomains of empathy on the decreased emotional arousal to the moral duty to not harm others in bvFTD.

Alternative explanations to the personal/impersonal distinction focus on the role of cognitive ToM or perspective taking, and the paradox of loss of empathy and social norm violations along with utilitarian-like responses with vmPFC lesions. In bvFTD, investigators have suggested that impaired mechanisms of ToM can account for decreased personal responses to moral vignettes (Gleichgerrcht et al., 2011), as well as perspective-taking, which is a form of self-projection that considers the thoughts and feelings of others but does not necessarily involve an emotional response (Rankin et al., 2005). Abnormal moral reasoning in bvFTD could be explained by a failure to recognize the personal nature of dilemmas due to dysfunction of the SN in recruiting the DMN (Chiong et al., 2013). Moreover, dysfunction of affective processes may allow bvFTD patients to consider personal moral dilemmas with a "greater good" calculation that is more typical for impersonal dilemmas. Preference for "greater-good" judgments could be explained by an increase in cognitive control, mediated by mechanisms based in the DLPFC or by alterations in the cognitive aspects of empathy (Rankin et al., 2005; Shamay-Tsoory, Aharon-Peretz, & Perry, 2009). However, these cognitive processes, or a utilitarian explanation, do not capture the loss of empathy, sociopathic behavioral tendencies, and non-care-based morality observed in bvFTD patients (Liljegren et al., 2015; Mendez, 2009; Rascovsky et al., 2011). One unifying explanation for these findings, and those from this study, is a normal struggle between emotional and cognitive heuristics, or rule-based guides based on a "commonsense" morality to act for the greater "beneficence" (Kahane, 2015), rather than postulating a philosophical opposition between deontological and utilitarian behaviors.

There are several potential limitations of this study. First, the total number of participants was small. Nevertheless, the level of participants per group was sufficient to demonstrate significant differences and a group–dilemma interaction effect on psychophysiology.

A second limitation was the absence of counterbalancing of the two moral dilemma presentations as responses to moral dilemmas can be susceptible to order effect (Liao, Wiegmann, Alexander, & Vong, 2012). The current study presented the same sequence of two dilemmas to all groups; however, any carryover effect would be present across all groups and would not necessarily affect group differences. Finally, the patients were not entirely comparable in dementia severity. The AD patients, however, were more impaired than the bvFTD patients and might be expected to be less engaged and reactive to the moral dilemmas, rather than the opposite results found in this study.

In conclusion, patients with bvFTD, whose neuropathology involves vmPFC, insula, and other paralimbic structures, were not only willing to cause instrumental, intentional harm in order to achieve a good end, but their willingness was associated with decreased emotional arousal and decreased evidence of the immediate, aversive emotional reaction to do no harm. In comparison to participants with AD or HCs, those with bvFTD had decreased conflict and discomfort, which correlates with a measure of social norms violations. These findings, coupled with the literature on bvFTD, are in agreement with the personal/impersonal distinction of emotional reactivity and suggest a reversion to reasoning processes for moral decision-making when prosocial emotions fail. Psychophysiological studies, with other moral dilemmas and in other neurological conditions, can further explore these mechanisms of moral decision-making in the brain.

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References

Baez, S., Couto, B., Torralva, T., Sposato, L. A., Huepe, D., Montanes, P., … Ibanez, A. (2014). Comparing moral judgments of patients with frontotemporal dementia and frontal stroke. *JAMA Neurology*, *71*(9), 1172–1176. doi:10.1001/jamaneurol.2014.347

Borg, J. S., Hynes, C., Van Horn, J., Grafton, S., & Sinnott-Armstrong, W. (2006). Consequences, action, and intention as factors in moral judgments: An fMRI investigation. *Journal of Cognitive Neuroscience*, *18*(5), 803–817. doi:10.1162/jocn.2006.18.5.803

Carr, A. R., Paholpak, P., Daianu, M., Fong, S. S., Mather, M., Jimenez, E. E., … Mendez, M. F. (2015). An investigation of care-based vs. rule-based morality in frontotemporal dementia, Alzheimer's disease, and healthy controls. *Neuropsychologia*, *78*, 73–79. doi:10.1016/j.neuropsychologia.2015.09.033

Chiong, W., Wilson, S. M., D'Esposito, M., Kayser, A. S., Grossman, S. N., Poorzand, P., … Rankin, K. P. (2013). The salience network causally influences default mode network activity during moral reasoning. *Brain: A Journal of Neurology*, *136*(Pt 6), 1929–1941. doi:10.1093/brain/awt066

Christensen, J. F., Flexas, A., Calabrese, M., Gut, N. K., & Gomila, A. (2014). Moral judgment reloaded: A moral dilemma validation study. *Frontiers in Psychology*, *5*, 607. doi:10.3389/fpsyg.2014.00607

Ciaramelli, E., Muccioli, M., Làdavas, E., & di Pellegrino, G. (2007). Selective deficit in personal moral judgment following damage to ventromedial prefrontal cortex. *Social Cognitive and Affective Neuroscience*, *2*(2), 84–92. doi:10.1093/scan/nsm001

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

Decety, J. (2011). The neuroevolution of empathy. *Annals of the New York Academy of Sciences*, *1231*, 35–45. doi:10.1111/j.1749-6632.2011.06027.x

Decety, J., & Howard, L. H. (2013). The role of affect in the neurodevelopment of morality. *Child Development Perspectives*, *7*(1), 49–54. doi:10.1111/cdep.12020

Decety, J., & Jackson, P. L. (2004). The functional architecture of human empathy. *Behavioral and Cognitive Neuroscience Reviews*, *3*(2), 71–100. doi:10.1177/1534582304267187

Decety, J., Michalska, K. J., & Kinzler, K. D. (2012). The contribution of emotion and cognition to moral sensitivity: A neurodevelopmental study. *Cerebral Cortex*, *22*(1), 209–220. doi:10.1093/cercor/bhr111

Diehl-Schmid, J., Perneczky, R., Koch, J., Nedopil, N., & Kurz, A. (2013). Guilty by suspicion? Criminal behavior in frontotemporal lobar degeneration. *Cognitive And Behavioral Neurology*, *26*(2), 73–77. doi:10.1097/WNN.0b013e31829cff11

Drevets, W. C., & Raichle, M. E. (1998). Suppression of regional cerebral blood during emotional versus higher cognitive processes: Implications for interactions between emotion and cognition. *Cognition and Emotion*, *12*, 353–385. doi:10.1080/026999398379646

Eslinger, P. J., Moore, P., Anderson, C., & Grossman, M. (2011). Social cognition, executive functioning, and neuroimaging correlates of empathic deficits in frontotemporal dementia. *Journal of Neuropsychiatry*, *23*(1), 74–82. doi:10.1176/appi.neuropsych.23.1.74

Figner, B., & Murphy, R. O. (2011). Using skin conductance in judgment and decision making research. In A. K. M. Schulte-Mecklenbeck & R. Ranyard (Eds.), *A handbook of process tracing methods for decision research* (pp. 163–184). New York, NY: Psychology Press.

Folstein, M. F., Folstein, S. E., & McHugh, P. R. (1975). "Mini-mental state". A practical method for grading the cognitive state of patients for the clinician. *Journal of Psychiatric Research*, *12*(3), 189–198. doi:10.1016/0022-3956(75)90026-6

Foot, P. (1967). The problem of abortion and the doctrine of the double effect. *Oxford Review*, *5*, 1–5.

Gleichgerrcht, E., Torralva, T., Rattazzi, A., Marenco, V., Roca, M., & Manes, F. (2013). Selective impairment of cognitive empathy for moral judgment in adults with high functioning autism. *Social Cognitive and Affective Neuroscience*, *8*(7), 780–788. doi:10.1093/scan/nss067

Gleichgerrcht, E., Torralva, T., Roca, M., Pose, M., & Manes, F. (2011). The role of social cognition in moral judgment in frontotemporal dementia. *Social Neuroscience*, *6*(2), 113–122. doi:10.1080/17470919.2010.506751

Greene, J., & Haidt, J. (2002). How (and where) does moral judgment work?. *Trends in Cognitive Sciences*, *6*(12), 517–523. doi:10.1016/S1364-6613(02)02011-9

Greene, J. D. (2013). *Moral tribes. Emotion, reason, and the gap between us and them*. New York, NY: Penguin Press.

Greene, J. D., Nystrom, L. E., Engell, A. D., Darley, J. M., & Cohen, J. D. (2004). The neural bases of cognitive conflict and control in moral judgment. *Neuron*, *44*(2), 389–400. doi:10.1016/j.neuron.2004.09.027

Greene, J. D., Sommerville, R. B., Nystrom, L. E., Darley, J. M., & Cohen, J. D. (2001). An fMRI investigation of emotional engagement in moral judgment. *Science*, *293*(5537), 2105–2108. doi:10.1126/science.1062872

Haidt, J. (2001). The emotional dog and its rational tail: A social intuitionist approach to moral judgment. *Psychological Review*, *108*(4), 814–834. doi:10.1037/0033-295X.108.4.814

Hauser, M. D., Cushman, F., Young, L., Jin, E., & Mikhail, J. (2007). A dissociation between moral judgments and justifications. *Mind & Language*, *22*(1), 1–21. doi:10.1111/j.1468-0017.2006.00297.x

Kahane, G. (2015). Sidetracked by trolleys: Why sacrificial moral dilemmas tell us little (or nothing) about utilitarian judgment. *Social Neuroscience*, *10*(5), 551–560. doi:10.1080/17470919.2015.1023400

Kahane, G., Everett, J. A., Earp, B. D., Farias, M., & Savulescu, J. (2015). 'Utilitarian' judgments in sacrificial moral dilemmas do not reflect impartial concern for the greater good. *Cognition*, *134*, 193–209. doi:10.1016/j.cognition.2014.10.005

Koenigs, M., Young, L., Adolphs, R., Tranel, D., Cushman, F., Hauser, M., & Damasio, A. (2007). Damage to the prefrontal cortex increases utilitarian moral judgements. *Nature*, *446*(7138), 908–911. doi:10.1038/nature05631

Liao, S. M., Wiegmann, A., Alexander, J., & Vong, G. (2012). Putting the trolley in order: Experimental philosophy and the loop case. *Philosophical Psychology*, *25*(5), 661–671.

Liljegren, M., Naasan, G., Temlett, J., Perry, D. C., Rankin, K. P., Merrilees, J., … Miller, B. L. (2015). Criminal behavior in frontotemporal dementia and Alzheimer disease. *JAMA Neurology*, *72*(3), 295–300. doi:10.1001/jamaneurol.2014.3781

Manfrinati, A., Lotto, L., Sarlo, M., Palomba, D., & Rumiati, R. (2013). Moral dilemmas and moral principles: When emotion and cognition unite. *Cognition & Emotion*, *27*(7), 1276–1291. doi:10.1080/02699931.2013.785388

McKhann, G. M., Knopman, D. S., Chertkow, H., Hyman, B. T., Jack, C. R., Jr., Kawas, C. H., … Phelps, C. H. (2011). The diagnosis of dementia due to Alzheimer's disease: Recommendations from the National Institute on Aging-Alzheimer's Association workgroups on diagnostic guidelines for Alzheimer's disease. *Alzheimers Dement*, *7*(3), 263–269. doi:10.1016/j.jalz.2011.03.005

Mendez, M. F. (2009). The neurobiology of moral behavior: Review and neuropsychiatric implications. *CNS Spectrums*, *14*(11), 608–620.

Mendez, M. F., Anderson, E., & Shapira, J. S. (2005). An investigation of moral judgement in frontotemporal dementia. *Cognitive and Behavioral Neurology*, *18*(4), 193–197. doi:10.1097/01.wnn.0000191292.17964.bb

Mendez, M. F., Chen, A. K., Shapira, J. S., & Miller, B. L. (2005). Acquired sociopathy and frontotemporal dementia. *Dementia and Geriatric Cognitive Disorders*, *20*(2–3), 99–104. doi:10.1159/000086474

Mendez, M. F., & Shapira, J. S. (2009). Altered emotional morality in frontotemporal dementia. *Cognitive Neuropsychiatry*, *14*(3), 165–179. doi:10.1080/13546800902924122

Miller, B. L., Darby, A., Benson, D. F., Cummings, J. L., & Miller, M. H. (1997). Aggressive, socially disruptive and antisocial behaviour associated with fronto-temporal dementia. *The British Journal of Psychiatry*, *170*, 150–154. doi:10.1192/bjp.170.2.150

Moll, J., & de Oliveira-Souza, R. (2007). Moral judgments, emotions and the utilitarian brain. *Trends in Cognitive Sciences*, *11*(8), 319–321. doi:10.1016/j.tics.2007.06.001

Moretto, G., Làdavas, E., Mattioli, F., & di Pellegrino, G. (2010). A psychophysiological investigation of moral judgment after ventromedial prefrontal damage. *Journal of Cognitive Neuroscience*, *22*(8), 1888–1899. doi:10.1162/jocn.2009.21367

Navarrete, C. D., McDonald, M. M., Mott, M. L., & Asher, B. (2012). Virtual morality: Emotion and action in a simulated three-dimensional "trolley problem". *Emotion*, *12*(2), 364–370. doi:10.1037/a0025561

Neary, D., Snowden, J. S., Gustafson, L., Passant, U., Stuss, D., Black, S., … Benson, D. F. (1998). Frontotemporal lobar degeneration: A consensus on clinical diagnostic criteria. *Neurology*, *51*(6), 1546–1554. doi:10.1212/WNL.51.6.1546

Oliver, L. D., Mitchell, D. G., Dziobek, I., MacKinley, J., Coleman, K., Rankin, K. P., & Finger, E. C. (2015). Parsing cognitive and emotional empathy deficits for negative and positive stimuli in frontotemporal dementia. *Neuropsychologia*, *67*, 14–26. doi:10.1016/j.neuropsychologia.2014.11.022

Piguet, O., Hornberger, M., Mioshi, E., & Hodges, J. R. (2011). Behavioural-variant frontotemporal dementia: Diagnosis, clinical staging, and management. *The Lancet Neurology*, *10*(2), 162–172. doi:10.1016/S1474-4422(10)70299-4

Possin, K. L., Feigenbaum, D., Rankin, K. P., Smith, G. E., Boxer, A. L., Wood, K., … Kramer, J. H. (2013). Dissociable executive functions in behavioral variant frontotemporal and Alzheimer dementias. *Neurology*, *80*(24), 2180–2185. doi:10.1212/WNL.0b013e318296e940

Rankin, K. P., Kramer, J. H., & Miller, B. L. (2005). Patterns of cognitive and emotional empathy in frontotemporal lobar degeneration. *Cognitive and Behavioral Neurology*, *18*(1), 28–36. doi:10.1097/01.wnn.0000152225.05377.ab

Rascovsky, K., Hodges, J. R., Knopman, D., Mendez, M. F., Kramer, J. H., Neuhaus, J., … Miller, B. L. (2011). Sensitivity of revised diagnostic criteria for the behavioural variant of frontotemporal dementia. *Brain: A Journal of Neurology*, *134*(Pt 9), 2456–2477. doi:10.1093/brain/awr179

Rosas, A., & Koenigs, M. (2014). Beyond "utilitarianism": Maximizing the clinical impact of moral judgment research. *Social Neuroscience*, *9*(6), 661–667. doi:10.1080/17470919.2014.937506

Shamay-Tsoory, S. G., Aharon-Peretz, J., & Perry, D. (2009). Two systems for empathy: A double dissociation between emotional and cognitive empathy in inferior frontal gyrus versus ventromedial prefrontal lesions. *Brain: A Journal of Neurology*, *132*(Pt 3), 617–627. doi:10.1093/brain/awn279

Tassy, S., Deruelle, C., Mancini, J., Leistedt, S., & Wicker, B. (2013). High levels of psychopathic traits alters moral choice but not moral judgment. *Frontiers in Human Neuroscience*, *7*, 229. doi:10.3389/fnhum.2013.00229

Tassy, S., Oullier, O., Mancini, J., & Wicker, B. (2013). Discrepancies between judgment and choice of action in moral dilemmas. *Frontiers in Psychology*, *4*, 250. doi:10.3389/fpsyg.2013.00250

Thomson, J. J. (1976). Killing, letting die, and the trolley problem. *The Monist*, *59*(2), 204–217. doi:10.5840/monist197659224

Young, L., & Koenigs, M. (2007). Investigating emotion in moral cognition: A review of evidence from functional neuroimaging and neuropsychology. *British Medical Bulletin*, *84*, 69–79. doi:10.1093/bmb/ldm031

Zhang, S., Hu, S., Chao, H. H., Ide, J. S., Luo, X., Farr, O. M., & Li, C. S. (2014). Ventromedial prefrontal cortex and the regulation of physiological arousal. *Social Cognitive and Affective Neuroscience*, *9*(7), 900–908. doi:10.1093/scan/nst064

Zhang, S., Hu, S., Chao, H. H., Luo, X., Farr, O. M., & Li, C. S. (2012). Cerebral correlates of skin conductance responses in a cognitive task. *Neuroimage*, *62*(3), 1489–1498. doi:10.1016/j.neuroimage.2012.05.036