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Original Article

Killing for the greater good: Action aversion and the emotional inhibition of harm in moral dilemmas☆

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ABSTRACT

Moral judgment is influenced by both automatic and deliberative processing systems, and moral conflict arises when these systems produce competing intuitions. We investigated the role of emotional arousal in inhibiting harmful action in a behavioral study of utilitarian tradeoffs in a 3D digital simulation of two classic "trolley" scenarios in which participants decided whether to harm one person in order to avert harm to five others. Physiological arousal was measured via skin conductance response in real time. Results showed that physiological arousal is increased in situations in which using personal harm is necessary to achieve a utilitarian outcome relative to when the same outcome can be achieved with impersonal harm, and is linked to a decreased likelihood of engaging in harmful action, though a test of mediation was not statistically significant. In addition, when the use of personal harm was required to save lives, arousal was higher *pre*-action relative to *post*-action. Overall, our findings suggest that physiological arousal may be part of an affective system that functions to inhibit harmful action against others.

1. Introduction

There is a long-standing tension between utilitarian and deontological philosophical perspectives on morality. The deontological tradition emphasizes the rights and duties of individuals as intrinsic axioms, regardless of the consequences (Broad, 1930). In contrast, utilitarianism is necessarily *consequential* in its judgment of action, seeking the maximum welfare for the greatest number (Mill, 1863). Consider a dilemma implemented by Greene, Sommerville, Nystrom, Darley, and Cohen (2001). You are with a group of people hiding from an aggressive militant group attempting to seek you out. If they find you, they will kill the entire group. You are holding a baby that begins to cry loudly, which will attract the attention of your pursuers. You can attempt to smother the baby to silence its cries, but in doing so you will kill it. For deontologists, the act of smothering the baby is immoral, not because of the consequences of doing it, but because we have a moral duty to avoid actions that cause harm. But for utilitarians, smothering a baby is not intrinsically wrong, and may be permissible if it saves a large group of people hiding from soldiers who would have otherwise heard its cries.

The *dual process* approach to moral psychology describes the historical tension between utilitarian and deontological philosophy as the competition between two separate psychological systems rooted in our species' neurocognitive architecture. Moral dilemmas arise when we contemplate pitting consequential considerations for a greater good against our non-consequentialist intuition to avoid harm, each generated by a distinct psychological system within the mind (Greene, 2013). In dilemmas such as the crying baby scenario above, one system judges the consequences of actions in utilitarian terms (e.g., "one harmed is better than many harmed"), and relies on processes that are controlled, deliberative, and logical. The other system is informed by affective feedback about one's action (e.g., "I feel terrible about this"), and relies on processes that are automatic, intuitive, and emotional.

The dual process perspective posits that utilitarian outcomes requiring harmful action can only occur when signals from the affective system impeding harmful action are quelled by the "cooler" deliberative

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processing areas of the mind involved in weighing the costs and benefits of a particular decision.[1] Conversely, our "hot" emotional aversion to harm may override consequentialist reasoning, stymieing the process of deliberate utilitarian action in favor of deontological judgments, particularly for intentionally harmful actions requiring the use of personal force (Greene et al., 2009). For example, in the classic trolley scenarios, most people judge it morally permissible to save the lives of five railway workers in the path of a runaway trolley by impersonally pulling a switch to divert the trolley to a sidetrack where it kills only one worker. However, when saving the five requires forcefully pushing a large man off a footbridge into the path of the oncoming trolley, most judge it to be morally wrong (e.g., Cushman, Young, & Hauser, 2006).

1.1. Action aversion

Past research has provided some support for the notion that the consideration of the consequences of one's actions, such as empathy for a victim in distress, makes the performance of harmful acts aversive (e.g., Batson, 1983; Batson & Ahmad, 2009). In contrast to such "outcome aversion" approaches to harm avoidance, other researchers posit that the aversion to harmful action may be triggered by the mere anticipation of the motor properties of a harmful action, without the consideration of its consequences (e.g., Blair, 1995). Congruent with this line of reasoning, Cushman, Gray, Gaffey, and Mendes (2012) found evidence for an automatic aversion to committing physical harm, evoked by the intrinsic properties of the action alone. Across two studies, research participants' autonomic nervous system activity was recorded while committing simulated harmful actions such as "stabbing" an experimenter with a rubber knife or "shooting" them in the face with a gun replica. They found that committing simulated harmful actions was associated with heightened autonomic activity relative to when the same actions were observed being committed by a third party.

The authors posit that humans may be endowed with a neurophysiological mechanism for harm avoidance, articulated as the *action aversion hypothesis*, which states that "physiological aversion can be triggered by only the motor or perceptual properties of harmful action" (Cushman et al., 2012, p. 3). When a person prepares for the performance of an act that would typically result in harm, the same physiological processes are activated as when harm would actually occur even if it is a mere simulated action. Additionally, that the autonomic activity occurred before and during the harmful acts, and decreased after the action was completed suggests that the physiological response has an inhibitory function (Cushman et al., 2012). According to Cushman et al., this mechanism operates as a function of the anticipation of the actions themselves, and does not necessarily depend on the "real world" consequences of the actions.

1.2. Evolutionary roots of an action aversion system

A critical component of the original dual-process approach as applied to action aversion is the notion that action aversion to first-person harm should be operative primarily when the anticipated harmful act requires the use of interpersonal force in close contact, and less so when the actions are conducted via impersonal action where causal chains are distally linked (Greene, Nystrom, Engell, Darley, & Cohen, 2004; Greene et al., 2009). There are at least two reasons to expect this distinction between personal and impersonal action for harm aversion, which we discuss below.

1.2.1. A phylogenetic by-product

The "hot" moral judgment system is likely to be most strongly activated when mentally simulating or engaging in violent actions with motor patterns that have deep phylogenetic roots that would be familiar to a range of primates due to our common ancestry. This system is markedly less active when considering harmful actions engaging the more recently evolved systems, such as those underlying the unique human ability for "cooler" abstract reasoning processes about impersonal harm requiring complex reasoning about both animate and inanimate mechanical causation. For example, pulling a lever that changes the direction of a trolley to avert a tragedy requires certain kinds of reasoning abilities not widely shared among mammals, and likely has more shallow phylogenetic roots than the cognitive abilities to process harmful action via personal contact.

1.2.2. A reputational adaptation

A functional approach to the moral psychology of harm suggests that harmful actions are aversive to the actor because of the potential costs involved. For example, harmful action, even if implemented for a net benefit to others, can lead to aggressive resistance or retaliation by the victim or third parties, and may have negative long-term reputational consequences. Such an automatic negative reaction to harm involving personal force may function to prevent actions for which the potential for plausible deniability of culpability is limited (DeScioli, Bruening, & Kurzban, 2011; Greene, 2013; Pinker, 2007). Consider, for example, the certainty with which we know Jack Ruby killed Lee Harvey Oswald, relative to the confidence we have that Oswald killed President John F. Kennedy. The details involved in each case are such that counterfactuals involving culpability are more readily generated for the assassination of Kennedy relative to the killing of Oswald.

In sum, an action aversion mechanism that produces an automatic reaction to personal harm subjectively experienced as negative arousal (e.g., fear, disgust) should be activated most strongly when actions require the use of personal force (pushing a bystander to their death to stop a trolley), and less so in impersonal interaction (flipping a switch to divert the trolley). The underlying reason for this could be a result of the phylogenetic age of mechanisms for performing complex vs simple motoric action, activation of reputation preservation mechanisms, or other factors not explored here. These functional explanations are not mutually exclusive, and do not contradict Cushman et al.'s (2012) or Greene et al.'s (2001) accounts of the proximate neurophysiological responses. The current research speaks to, but does not directly test, these ultimate explanations. Rather we examine the implications of the dual process model within the action aversion paradigm.

1.3. The present research

The notion of action aversion is particularly relevant in moral dilemmas contrasting impersonal harm at a distance versus harm that is "up-close-and-personal." The variants of the trolley dilemma described above illustrate the relevance of the action aversion hypothesis, as research shows that utilitarian judgments in surveys are more likely when the hypothetical harm is imagined to be committed impersonally compared to personally (e.g., Cushman et al., 2006).

Greene et al. (Greene et al., 2004; Greene, 2007) provided preliminary evidence for the presence of a dual-process system. Utilizing neuroimaging techniques and examining neural activation, they found that when participants imagined a dilemma requiring personal force (e.g., pushing a person) to kill one person to save five others, "a prepotent, negative emotional response" was activated (Greene, 2007, p. 322). The "hot" response served to inhibit the initial harmful act in some, whereas the "cooler" deliberative system allowed others to overcome the response and engage in the action.

[1] Classifying the outcome of a decision as utilitarian is often presumed to imply that an individual reached the decision through the use of conscious utilitarian reasoning, in which an individual decided whether to take action on the basis of which option would maximize the welfare of those involved in the dilemma. This assumption may not hold, as the true reasons behind a moral judgment may be inaccessible or simply post-hoc rationalizations (Haidt, 2001). Thus, it should be noted that throughout this article the use of the terms utilitarian and deontological denote a classification of an outcome that could be perceived as utilitarian or deontological, but not that a particular person is reasoning with such specific philosophical premises in mind.

Here we present an experiment designed as a *behavioral* simulation of these two classic moral dilemmas as an ideal method for investigating the workings of the action aversion system. Moral dilemmas were presented to research participants in digitized, three-dimensional (3D) simulations (i.e., virtual reality) in which actions were measured behaviorally in real-time, with the sights and sounds of people in distress in stark relief. Critically, we test the predictions of dual-process theory as applied to the action aversion paradigm.

1.3.1. The omission bias

Consistent with the deontological perspective on moral psychology, there is substantial research demonstrating that humans show an "omission bias," in which actions that result in harm are judged as morally worse than omissions of actions that result in an equivalently harmful outcome (Baron & Ritov, 2004; Cushman et al., 2006; Hauser, Tonnaer, & Cima, 2009; Navarrete, McDonald, Mott, & Asher, 2012). In terms of its evolutionary origins, omission of action lends itself readily to the plausible deniability of culpability for harmful outcomes (DeScioli et al., 2011; Hoffman, Yoeli, & Navarrete, 2016; Pinker, 2007). Accordingly, we expect that people will experience less psychological conflict for harmful outcomes to others when the outcome inevitably unfolds by omission rather than commission of an action.

1.3.2. Emotional inhibition of action and pre-decision conflict

The inhibitory effects of the action aversion reaction – a marked increase in physiological arousal – are expected to operate most strongly when the anticipated act involves physical contact with another individual. As such, individuals may be less likely to use personal force against a person to save five because the psychological conflict evoked produces an emotional response so aversive that consequentialist reasoning for the "greater good" does not override the non-consequentialist impulse to "do no harm." Therefore, we expect that situations requiring personal harm to achieve a utilitarian outcome will more strongly activate the action aversion system than situations not requiring personal harm, that is, they will produce greater physiological arousal. This increased arousal should subsequently function to reduce the likelihood of making a utilitarian choice. This would confirm the findings of Greene et al. (Greene et al., 2004; Greene, 2007) as well as increase the ecological validity of the findings by demonstrating them in a simulated environment requiring real action.

Furthermore, given our functionalist perspective on the utility of an action aversion system, the temporal patterns of physiological arousal may reflect an important aspect of its putative design. A system that functions to inhibit harmful behavior would be most useful if its effects were operative in the moments of contemplation preceding a decision to act. As such, we expect that aversive arousal will be greatest during the decision making process preceding an anticipated harmful action relative to the moments following the action. After the action has occurred, the arousal can no longer function to inhibit the behavior.

1.3.3. The experimental environment

Virtual reality (VR) environments allow for the presentation of stimuli and the measurement of behavior that would otherwise be practically implausible or unethical if conducted in standard behavioral contexts. Furthermore, with physiological reactions measured in real-time, key moments of arousal can be measured in ways otherwise infeasible in standard environments. Most important, this method lends itself to our goal of testing predictions on the workings of an action aversion system, such that a rigorous investigation demands that one's emotions are engaged in situations that require actual physical action, even if the outcome does not end in actual harm to real persons. Indeed, that is an important empirical claim of the enterprise, that such effects should be found even when the actor knows that they are only simulating harm (Cushman et al., 2012). Finally, VR environments allow for increased control over presentation stimuli, enabling the exact replication of experimental conditions presented to each participant including the use of digital, 3D "confederates" (Blascovich et al., 2002).

Studies of the behavioral reactions in clinical research such as fear of heights (Coelho, Waters, Hine, & Wallis, 2009) combat-related posttraumatic stress (Rothbaum, Rizzo, & Difede, 2010), and commercial applications such as the experience of free-fall in a sky-diving simulator (Takahashi, 2013), suggest a type of realism that is sufficient for our purposes. Yet it is worth clarifying that we do not claim that the observations within VR environments are interchangeable with natural environments, given that behavior in the latter clearly has greater legal, reputational, physical, and long-term emotional consequences for the actors. However, we emphasize that this is an important feature of the method, and not a bug, as it allows us to largely rule out the extent to which calculations of the consequences of one's actions affect the workings of the motoric, mechanistic processes at play when confronted with moral dilemmas.

1.3.4. Summary and predictions

In sum, we conducted an experiment in an immersive, 3D virtual environment where research participants were confronted with moral dilemmas pitting action versus omission, and interpersonal force versus impersonal action, in a tradeoff between lives saved and lost. Participants' level of psychological conflict due to activation of the action aversion system was inferred from their physiological arousal, measured via skin conductance response in real time as participants contemplated and acted out their decisions.

1.3.4.1. Prediction 1. Synthesizing previous theory and research on the omission bias and harm aversion, we expected that participants would be less conflicted when in a situation in which no action was required to bring about the utilitarian outcome, relative to when the same outcome required action. That is, we expected physiological arousal to be greater among participants when in an action condition, relative to an omission condition. Support for this prediction would replicate and extend past findings (Navarrete et al., 2012).

1.3.4.2. Prediction 2. Based on the evolutionary approach to action aversion described above, we expected that mean physiological arousal would be greater when participants were confronted with a dilemma in which saving lives required the use of personal force against another (personal harm condition, i.e., the footbridge dilemma), relative to when the utilitarian outcome could be achieved via impersonal action (impersonal harm condition, i.e., the switch dilemma).

1.3.4.3. Prediction 3. Building on the second prediction, given that higher arousal is expected to reduce the likelihood of committing harm, it should follow that individuals will be less likely to make a utilitarian decision when doing so requires committing personal harm than when it does not. In other words, participants should be less likely to push the man off of the platform, than to flip the switch to divert the trolley, in order to save five lives.

1.3.4.4. Prediction 4. Given the hypothesized role of emotional arousal in the inhibition of harmful action, as well as the expectation that emotional aversion to harm is linked to the means by which harm is carried out, we predicted that physiological arousal would mediate the relationship between dilemma type and utilitarian action. That is, we expected that the footbridge dilemma would produce greater arousal than the switch dilemma, owing to the discrepancy in personal versus impersonal harm, and that this difference in arousal would predict whether the participant chose to make a utilitarian or deontological decision, such that higher arousal would be associated with a deontological decision.

1.3.4.5. Prediction 5. Physiological arousal is argued to reduce the likelihood of committing harm and therefore has diminishing utility for action aversion mechanisms once the decision to engage in harm has been enacted. As a result, we expected that, among participants who engaged in harmful action to bring about a utilitarian action, that arousal would be higher before the action took place than following action. In particular, we expected this effect would be strongest in situations that required personal harm, as this situation is expected to generate greater arousal pre-action in order to reduce the likelihood of committing harm with potentially severe reputational consequences.

2. Methods

2.1. Participants

Two hundred and seventy five undergraduate students from the psychology research subject pool at Michigan State University were recruited for participation for a study on "Attitudes in Action in a 3D Virtual World." Observations were excluded for the following reasons: technical difficulties with physiological recording ($n = 16$) or with the stimulus presentation equipment ($n = 23$), misunderstanding instructions or noncompliance ($n = 13$), and voluntarily discontinuing participation ($n = 2$). Fifty-three observations were dropped from the analyses in total, resulting in a final sample of 222 individuals (81% White; 65% female), though individual analysis sample sizes vary due to condition-specific difficulties scoring physiological arousal.

2.2. Materials and measures

2.2.1. Physiological arousal

Physiological arousal was measured via skin conductance responses (SCR), recorded from electrodes placed on the second and fourth fingers of each participant's non-dominant hand. Responses were recorded continuously for the duration of the experiment using Biopac MP150 hardware and AcqKnowledge software (500 Hz sampling rate). Recordings were analyzed using MindWare EDA, with minimum detection parameters set to 0.02 μS. Observations containing movement artifacts, dropped signals, or otherwise corrupted segments were dropped from the analyses for technical difficulties (see Section 2.1). Digital signals from the stimulation presentation software automatically marked the physiological recording files for the timing of events in each dilemma.

Skin conductance data was analyzed using phasic amplitude, which is sensitive to changing events and stimuli over time. Observations were log-transformed and then standardized (z-scores) within-participants to normalize the distribution of responses and minimize the effects of between-subject variance in baseline response (Boucsein et al., 2012; Braithwaite, Watson, Jones, & Rowe, 2013; Dawson, Schell, & Filion, 2000). A summary of the descriptive statistics is provided in Table 1.

2.2.2. Stimulus presentation

A head-mounted display (HMD) with an enclosed stereoscopic monitor was used to deliver high-definition images to the participant via cables connected to a computer running the simulation (HMD Model: nVisor SX by NVIS). Visual stimuli were rendered in Vizard Virtual Reality Software Toolkit by technicians at Worldviz, LLC. The bystanders appeared as digital avatars, rendered from a customized version of the avatars licensed in Vizard's Complete Characters software package. Mounted speakers were configured for spatially relevant auditory stimuli, created by Worldviz technicians and modified by the researchers.

Table 1
Means and standard deviations for SCR arousal level (standardized within-participant), by condition and outcome group.

Condition	Outcome	*n*	*M* (*SD*)
Impersonal - omission	Control	218	−0.17 (0.45)
Impersonal - action	Total	221	0.04 (0.39)
	Utilitarian	205	0.03 (0.39)
	Deontological	16	0.16 (0.35)
Personal - omission	Control	219	−0.12 (0.31)
Personal - action	Total	221	0.13 (0.22)
	Utilitarian	115	0.12 (0.20)
	Deontological	106	0.15 (0.25)
Impersonal - action	Pre-action	94	0.01 (0.69)
	Post-action	94	0.16 (0.62)
Personal - action	Pre-action	94	0.34 (0.54)
	Post-action	94	0.02 (0.34)

Note. Participants who chose to kill unnecessarily in the omission trials were dropped from subsequent analysis. Therefore, no separation by outcome group is provided for the omission conditions.

2.2.3. Behavioral measurement

Participant behavior was tracked and recorded using Worldviz' PPT-X Precision Motion Tracking system, composed of four cameras that track the movement of wireless sensors attached to participants. Sensors were attached to the top of the HMD worn by participants, as well as their wrists. A force-feedback joystick recorded the participant movement of a lever that controlled the direction of a railcar within the 3D environment during the impersonal switch condition, but was inoperable during the personal footbridge condition. Participant action was recorded using Vizard software that saved event signals of stimuli and the location and behavior of each participant.

2.3. Procedure

Participants were fitted with skin conductance electrodes, tracking sensors, and the HMD. The virtual environment unfolded with the participant standing on a platform overhanging a railway track stretching through a canyon-like environment. Behind the participant, a single track stretched to the horizon. In front of the participant, the track split into two, with one continuing straight though a ravine, and a sidetrack veering into another ravine.

A series of practice trials of 60s duration were administered in order to habituate participants to the environment and tasks. Directly in front of the participant was a rail switch that could be manipulated in a lever-like fashion via a force-feedback joystick. Through instructions, participants were guided to observe the effects of pulling the switch on the path of a railcar. In half of the practice trials, the switch was inoperable. In these instances, participants were guided through instructions to a set of stacked barrels located behind them. The barrels could be pushed off the platform onto the track below if the participant walked within arms distance of the barrels and extended their hand past the surface plane of the top barrel. Participants observed the barrel falling onto the track below, where its weight stopped the railcar from continuing down the main track, but was crushed in the process. When no action was taken, the railcar continued straight down the track through the steep ravine. During practice trials no explanation for being asked to complete these tasks was given so as not to lead the participants into taking a particular course of action during the experimental trials.

Following the practice trials, participants were presented with the experimental trolley simulations. Simulations were presented in a 2×2 within-subjects design such that each participant experienced all four conditions: Personal/Action, Personal/Omission, Impersonal/Action, Impersonal/Omission. Each condition contained a single trial of the dilemma. Participants were presented with the footbridge dilemma block first, followed by the switch dilemma

block.[2] Within each block, the order of action/omission was set so that the action variant was presented first. Video capture examples of the dilemmas are provided at: http://www.cdnresearch.net/vr-dilemmas.html.

2.3.1. Impersonal harm (switch)

The standard trolley "switch" dilemma (Thomson, 1985) was used as the context in which utilitarian ends were achieved via the use of impersonal action. Participants were presented with the following digital message within the HMD:

> "Railcars travel to their destination by force of gravity, and change tracks if the lever is switched between right and left, but will arrive at their destination on either track. Travelers on foot often use the tracks as a shortcut. However, they are unable to see or hear the approaching railcars until it is too late, as the steep ravines prevent escape."

Simulations began with the participants on the platform able to view avatars on the ground walking away from the platform with one individual heading toward one track, and five individuals heading toward the opposite track. After 20s, a moving railcar became audible, and was visible in the distance over the left shoulder of the participant. Becoming louder as it approached, the railcar reached the switch platform after 20s (40s total), traveled underneath the platform, and either continued to the main track if the switch was not pulled, or veered onto the side track when the switch was pulled. Screams of distress from either one or five agents audibly echoed from the ravines depending on the direction of the boxcar and the location of the avatars. Screams abruptly ended at impact, and the environment faded to black.

In the action condition variant, pulling the switch generated the utilitarian outcome: the railcar veered away from five human avatars on the main track onto a side track where only one avatar was situated. In the omission variant, *not* pulling the switch resulted in the railcar continuing down the main track, crushing one person on this track, but allowing the five on the side track to survive.

2.3.2. Personal harm (footbridge)

The "footbridge" dilemma was used as the context in which utilitarian gains were obtained by harming another person through the use of personal force. Participants were presented with the following text viewed within the HMD:

> "Railcars travel to their destination by force of gravity, and will continue on the main track unless a heavy object is in the path of an oncoming railcar or its direction is changed using a rail switch. Travelers on foot often use the tracks as a shortcut. However, they are unable to see or hear the approaching railcars until it is too late, as the steep ravines prevent escape. The rail switch is inoperable, and there are no barrels currently available. However, a person standing at the edge of the platform is heavy enough such that if he is pushed to the track, he will certainly be crushed by the railcar, but the railcar will be stopped."

As in the switch condition, simulations begin with avatars on the ground walking away from the switch platform toward the ravines. However, five people travel on either the main track (action condition) or the sidetrack (omission condition). Movement of the joystick produced no change in the position of the switch nor the direction of the railcar. After 20s, the approaching railcar became audible and visible in the distance. At 40s it reached the platform and continued to the main track if the man was not pushed in its path.

In the action condition variant, pushing the man off the platform generates the utilitarian outcome. The railcar is brought to a stop, and the five human avatars on the main track are spared. The person pushed to the track screams as he falls from the platform, and is crushed by the oncoming railcar before it comes to a halt. If the man was not pushed, screams from five avatars were heard as the railcar approached, which abruptly ended at impact. In the omission variant, not pushing the man resulted in the railcar continuing down the main track, having no effect on the five people on the side track who continue to travel safely.

3. Results

3.1. Prediction 1

We began our analyses by testing the prediction that emotional arousal would be greater when contemplating a dilemma in which action was required to produce a utilitarian outcome as compared to a dilemma in which the utilitarian outcome would unfold without any intervention. A repeated measures two-way ANOVA was conducted in which dilemma type (personal harm vs impersonal harm) and the response required to bring about a utilitarian outcome (action vs omission), as well as their interaction, were included as predictors of physiological arousal (see Table 1 and Fig. 1). Providing support for the omission bias prediction, results revealed a main effect for the response required ($F(1, 215) = 89.76$, $p < 0.001$, $\eta_p^2 = 0.30$) such that a utilitarian outcome that could be brought about by omission led to lower average arousal ($M = -0.14$, $SE = 0.02$) than when the utilitarian outcome required action ($M = 0.08$, $SE = 0.01$). There was also a main effect of the dilemma type ($F(1, 215) = 6.67$, $p = 0.010$, $\eta_p^2 = 0.03$) such that the personal harm condition (footbridge) was associated with greater physiological arousal ($M = 0.01$, $SE = 0.01$) than the impersonal harm (switch) condition ($M = -0.07$, $SE = 0.02$). There was no interaction between the factors, suggesting that taking action to enact the utilitarian outcome was associated with increased arousal compared to not taking action to achieve the same outcome, and

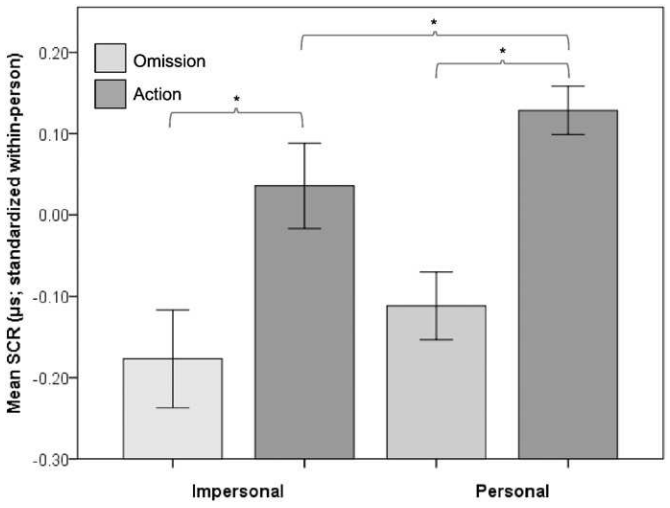

Fig. 1. Mean arousal level by dilemma type and response required to produce utilitarian outcome. * $p < 0.05$. Error bars denote 95% confidence interval.

[2] Initially, participants completed the switch condition first and then the footbridge. However, high rates of utilitarian behavior were observed in the footbridge condition that far exceeded those obtained in self-report variants of the dilemma. It was assumed that this was the result of a desire to maintain consistency across the two dilemmas. To circumvent this, participants were made to always complete the footbridge condition first, followed by the switch condition. Of the 222 participants, 37 received the switch conditions first, and 185 received the footbridge conditions first. The action and omission variants of these dilemmas were presented such that the action condition occurred first, and the omission condition occurred second. This decision was made due to the fact that the most crucial trials for the current research are those pertaining to action. If these appear first, responses cannot be affected by one's response during the omission trials.

that this pattern was consistent across both the personal and impersonal condition variants.

3.2. Prediction 2

Next, we tested the notion that participants would be more psychologically conflicted when presented with a dilemma where the utilitarian outcome was realized through the use of personal harm, relative to when it was realized via impersonal action. In doing so, we examined physiological arousal solely in conditions requiring action—contrasting participants' arousal in the personal versus the impersonal harm conditions.

Consistent with expectations, a paired samples *t*-test indicated that mean arousal was higher in the personal harm condition ($M = 0.13$, $SD = 0.22$) relative to the impersonal harm condition ($M = 0.04$, $SD = 0.39$; $t(220) = 2.73$, $p = 0.007$, $\eta^2 = 0.03$). That is, participants showed greater arousal in the footbridge dilemma where they had to push a man off the platform to stop the railcar from killing five individuals, than in the switch dilemma where they had to flip a switch to diver the railcar to a track with one individual instead of five. However, as noted in the results for prediction 1, the difference in arousal between personal and impersonal conditions did not interact with whether the condition required action or omission. Thus, the personal harm condition increased arousal, but did so whether or not personal force was actually needed to produce a utilitarian outcome.

3.3. Prediction 3

Given that a higher level of arousal was observed in the personal harm condition relative to the impersonal harm condition, it follows that individuals would be predicted to be less likely to make a utilitarian decision when doing so requires committing personal harm than when it does not. Accordingly, decision-making in the action conditions revealed that approximately 93% of participants chose the utilitarian decision in the switch dilemma, but only 52% chose the utilitarian decision in the footbridge dilemma (see Table 2).

3.4. Prediction 4

The results above demonstrate that dilemmas involving personal harm, relative to impersonal harm, produce more physiological arousal and a lower probability of utilitarian action. Given that arousal is expected to reflect psychological conflict over committing harm in order to bring about a utilitarian action, we expected that arousal would mediate the relationship between the dilemma type and utilitarian action. To test this prediction, we conducted a repeated measures mediation analysis using the SPSS Macro MEMORE (version 1.1; Montoya & Hayes, in press). Using only data from the action condition variants, the personal versus impersonal condition was modeled as the predictor variable, the difference in arousal between these conditions was entered as the mediating variable, and the difference in utilitarian decision-making between conditions was entered as the outcome variable. Montoya and Hayes (in press) recommend that mediation be inferred on the basis of the indirect path from the predictor to the outcome, through the mediator. Significance is determined based on a boot-strapped confidence interval of the indirect effect. Results of the analysis, with 10,000 bootstrapped samples, produced a small indirect effect in the predicted direction ($b = -0.01$, $SE = 0.01$) in which the 95% bootstrapped CI overlapped with zero [−0.04, 0.0008], indicating a non-significant indirect effect at this level. Relaxing the confidence interval to 90% produced an interval that excluded zero (CI [−0.03, −0.0008].

Table 2
Proportion of deontological vs utilitarian outcomes, by condition.

Condition	Outcome group	*n*	%
Impersonal - omission	Control	222	
Impersonal - action	Utilitarian	206	93
	Deontological	16	7
Personal - omission	Control	222	
Personal - action	Utilitarian	115	52
	Deontological	107	48

Note. Participants who chose to kill unnecessarily in the omission trials were dropped from subsequent analysis. Therefore, no separation by outcome group is provided for the omission conditions.

3.5. Prediction 5

Finally, we examined the prediction that, among participants who were willing to take action to kill for the greater good, physiological arousal would be highest before the action was taken (pre-action arousal), relative to arousal after the action was completed (post-action arousal). In testing whether differences in pre- and post-action emotional arousal were linked to outcomes, the analysis of autonomic responses was limited to a 15-second pre- and post-action window. Only participants who had at least one SCR during both windows for each dilemma were included in the analysis, reducing the sample to 94 individuals.

A repeated-measures two-way ANOVA was conducted with time (pre- and post-action) and dilemma (trolley vs footbridge) predicting physiological arousal. Results indicated no main effect of time or dilemma, but an interaction of the two factors ($F(1, 93) = 16.23$, $p < 0.001$, $\eta_p^2 = 0.15$; see Fig. 2). Breaking down the interaction revealed that there was an effect of time in the footbridge condition ($F(1, 93) = 18.92$, $p < 0.001$, $\eta^2 = 0.17$) such that pre-action arousal ($M = 0.34$, $SE = 0.06$) was greater than post-action arousal ($M = 0.02$, $SE = 0.04$). However, there was no effect of time in the switch condition ($F(1, 93) = 2.67$, $p = 0.106$, $\eta^2 = 0.03$), that is, there was no difference in arousal before action ($M = 0.01$, $SE = 0.07$) compared to after action ($M = 0.16$, $SE = 0.06$). The analysis was also conducted with the full sample by replacing the missing SCRs with SCRs of zero-magnitude. The results produced the same interaction pattern ($F(1, 221) = 12.17$, $p = 0.001$, $\eta_p^2 = 0.05$) in which post-action arousal was lower than pre-action arousal, but only in the footbridge dilemma ($F(1, 221) = 25.55$, $p < 0.001$, $\eta^2 = 0.10$).

4. Discussion

We investigated the role of emotional arousal in the working of a hypothesized action aversion system. We argue that this system functions

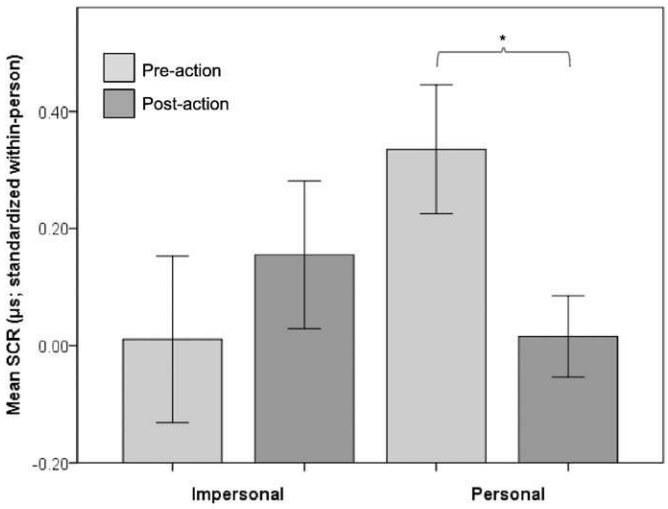

Fig. 2. Mean arousal level across conditions, pre- vs. post-action. * $p < 0.05$. Error bars denote 95% confidence interval.

to generate an aversive response when anticipating harmful action. We predicted and found that moral dilemmas requiring harmful action (personal and impersonal) to achieve a greater good were more emotionally arousing than situations in which a similar outcome was realized via the omission of action.

In dilemmas requiring action, situations involving personal harm were more emotionally arousing than those involving impersonal harm and less likely to result in utilitarian action. These findings are consistent with the expectation that individuals in situations requiring the use of personal, physical force to achieve their objectives did so with great trepidation, and against their non-consequentialist moral intuitions. Integrating these findings, we provide preliminary evidence that the effect of personal versus impersonal harm on utilitarian action may be mediated by physiological arousal, implying that arousal may serve a key role in preventing harm in the action-aversion system. However, the very small size of the indirect effect suggests that much caution is needed in drawing conclusions about the temporal pattern of findings.

Finally, we found that emotional arousal before taking action was higher than after the action was completed in the footbridge dilemma, but that this pattern was not found in the standard switch dilemma. These findings are consistent with the argument that physiological arousal ought to be highest before harmful acts are committed, given the diminishing marginal utility of emotional arousal once the decision to harm another has been made.

4.1. Reputation management

The results are broadly consistent with a functionalist understanding of an action aversion system that inhibits harmful action out of reputational concerns. Indeed, research has demonstrated that a reputation for making more deontological moral judgments is associated with being perceived as more moral and trustworthy, and that such individuals are more likely to be preferred as social partners (Everett, Pizarro, & Crockett, 2016; Sacco, Brown, Lustgraaf, & Hugenberg, 2016). In accordance with this, greater arousal was observed for situations in which one's actions could be linked to harmful outcomes, than when the absence of action produced the same outcome. Additionally, for action trials, arousal was elevated for dilemmas in which the action producing harm had a direct and personal association with the harmful outcome, than when the action was more distally related to the harm. In brief, as the culpability for harm became more apparent, arousal increased.

Consistent with the findings of Cushman et al. (2012), we also found that arousal is greater before committing a harmful action than after. This is consistent with the idea that arousal is functioning to prevent the action from occurring, potentially to avoid reputational damage. This pre-action increase in arousal was observed only for the personal harm condition, but this is also consistent with a reputational explanation, as one's reputation is in less jeopardy when harm is committed via the distal action of flipping a switch versus pushing a man to his death.

We also discussed the possibility that arousal would be greater for dilemmas that activate phylogenetically older systems of causal reasoning that lead to harm (i.e. pushing someone to their death) versus dilemmas that require more abstract and complex causal reasoning (i.e. flipping a switch to divert a trolley). Though plausible, this explanation does not offer an explanation for why omission should produce less arousal than action, particularly considering that this effect was obtained for both dilemma types. Thus, overall we think that the full pattern of findings presented here are most consistent with a reputational explanation, but certainly cannot rule out these alternative (though not mutually exclusive) explanations.

4.2. Limitations

Observationally focused, and without corroborating self-report data pertaining to intention of participants throughout each trial, it is difficult to draw strong conclusions about the definitive application of our findings to theory. We understand this is a methodological weakness of the present study. However, we offer speculation as to the appropriate application and fit of our findings within the broader literature.

Our findings deviate from past research in that more participants engaged in harmful action to bring about a utilitarian outcome than is often seen in surveys utilizing the same or very similar situations (Cushman et al., 2006; Hauser, Cushman, Young, Kang-Xing Jin, & Mikhail, 2007). For example, Hauser and colleagues reported that 85% of participants indicated that it was morally permissible to act in the switch dilemma (versus 93% in the current study; 90.5% in Navarrete et al., 2012), and 12% of participants judged action in the footbridge condition to be permissible (versus 52% in the current study). A similar pattern of discrepancy between surveys and virtual dilemmas was reported by Patil, Cogoni, Zangrando, Chittaro, and Silani (2014) in their examination of impersonal moral dilemmas (e.g., the switch dilemma), as well as Francis et al. (2016), such that participants were more likely to make utilitarian decisions when presented via VR as compared to their judgments when the dilemmas were presented in-text.

One explanation for the survey-VR discrepancy in utilitarian action is that participants identify less with a digitized human form, or perceive them as dehumanized in such a state, and therefore feel less invested in making a thoughtful decision. However, Patil et al. (2014) found that participants, despite being more utilitarian in the VR dilemmas, experienced greater arousal than in the text presentation of the dilemmas (after controlling for general differences between presentation modes). This implies that participants are *more* engaged in the VR dilemma, rather than being disconnected. Consequently, it may be that this increased arousal is the source of the discrepancy, such that having a vivid visual representation of the lives to be lost by failing to act in a utilitarian manner overwhelms the arousal associated with having to utilize harmful action for the greater good. Additionally, by its very nature, the experience of the virtual dilemmas in this study is first-person, whereas survey questions are often framed in the third-person: "*is it morally permissible to do x*." This can also be construed as the difference between judgment and action, and indeed, past research has found greater endorsement of utilitarian decisions when questions are phrased in terms of personal action versus moral judgment (Tassy, Oullier, Mancini, & Wicker, 2013).

Another consideration given the nature of experimental research on undergraduate student populations is demand characteristics. Participants come to a laboratory in order to 'participate' in an experiment; as the footbridge and switch dilemma present a situation where the participant either makes an action, or stands there and does nothing, it is plausible (from the participant's perspective) that the experimenter is expecting them to 'do' something in the experiment.

Further, recent findings detail concerns about the methodological limitations of classic 'sacrificial dilemmas,' including an increased prevalence (and awareness) of the contents of the dilemma, a lack of ecological validity, and the elicitation of more 'humorous' responses than serious moral deliberation (Bauman, McGraw, Bartels, & Warren, 2014). Yet participants often report that their experience facing moral dilemmas is unpleasant, implying that they do indeed take the dilemma seriously (e.g., Christensen, Flexas, Calabrese, Gut, & Gomila, 2014; Lotto, Manfrinati, & Sarlo, 2014). All things considered, we remain agnostic about the high rates of utilitarian action in VR dilemmas, relative to survey data. However, inasmuch as Bauman et al. (2014) expound the limitations of sacrificial dilemmas in psychological research, in the present study, participants experienced real-time psychological conflict regarding their decision, and that conflict (expressed via physiological arousal) was predictive of behavior.

There are also methodological limitations to our design. First, owing to the difficulty of working with virtual reality, only a single dilemma was used for each condition. This limits the generalizability of our findings, as it is possible the pattern of findings is specific to these variants of the trolley problem. Conditions were also not counter-balanced (see

Footnote 2). This makes it difficult to assess the impact of order effects in our within-subjects design, which is an important limitation to consider when interpreting these findings (Bartels, Bauman, Cushman, Pizarro, & McGraw, 2016). Additionally, we note a key limitation in the comparison of the footbridge and switch conditions. We observed a difference in arousal between the two conditions and attributed it to the prospect of committing personal versus impersonal harm, but the conditions also differ in the presence of the avatar on the footbridge. It is possible that the elevated arousal can be explained by such a confound. We view this explanation as unlikely for a few reasons. First, the arousal has predictive power in the mediation model (although the effect is not statistically significant). This implies that the arousal is not merely an artifact of the stimuli of the environment, but rather a response to the anticipation of taking a personally harmful action. Arousal is also elevated in the action variant of the footbridge dilemma relative to the omission variant, implying that the presence of the avatar is not the only source of arousal when contemplating personal harm.

We also note that the footbridge omission condition does not provide the proper comparison to the action condition. In the action variant, taking action leads to one death, whereas not acting leads to five deaths. The omission variant should therefore reverse this, such that acting would lead to five deaths, and not acting would lead to one death. However, what actually occurs in the omission variant is that acting leads to one death, and not acting leads to no deaths. This asymmetry could provide an alternative explanation for the reduced arousal in the footbridge omission condition relative to the action condition. Yet, this cannot provide a full explanation of the predicted omission bias, as the difference in arousal is displayed for the switch conditions where there is a proper control.

We also note that there are at least two different explanations for the source of the arousal that is observed in response to these moral dilemmas. Our perspective is that the arousal reflects an aversive emotional response to committing a harmful action, and that it should be particularly elevated when the desire to "do no harm" conflicts with a rational consideration of utilitarian outcomes. Alternatively though, the arousal could simply be the byproduct of simultaneous activation of automatic processes that diverge with controlled processes. It is not possible to distinguish between these explanations in the current design. Yet, we would suggest that the preliminary evidence linking arousal to a reduced likelihood of engaging in utilitarian action, as well as the drop-off in arousal following action, are more consistent with a perspective in which arousal plays a causal role in inhibiting harmful behavior.

5. Conclusion

It is clear that physiological arousal plays a critical role in the proximate operation of moral judgment and behavior. There are promising patterns of psychophysiological arousal that suggest a relationship between intuitive, automatic information-processing, and top-town inhibitive processing, leading us to conclude that humans may indeed possess an 'action aversion' mechanism that functions to inhibit behavior that would incur the reputational consequences inherent to harmful interpersonal actions.

Data availability

The data associated with this research are available at: osf.io/aykxg.

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