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Cognitive load and moral decision-making in moral dilemmas under virtual reality: the role of empathy for pain

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Abstract
Moral decision-making is the internal process of individuals making choices regarding moral norms or social values. Based on the dual-process theory, this study investigated how cognitive load, empathy for pain, presentation modes, and moral dilemmas influence moral decision-making tendencies. Experiment 1 investigates the impact of cognitive load on moral decision-making tendencies in individuals under text-based and virtual reality (VR) moral dilemmas. Experiment 2 explores the influence of moral dilemmas, cognitive load, and empathy for pain on moral decision tendencies in a brain-machine interface-based VR environment. The results showed that individuals with high cognitive load demonstrated reduced mental effort and increased relaxation degree when experiencing empathy for pain. In a VR environment, individuals facing impersonal dilemmas and those experiencing high cognitive load were more likely to make utilitarian decisions when feeling empathy for pain. The study revealed the mechanisms by which cognitive load and empathy for pain affected moral decision tendencies in virtual reality, elucidating the role of empathy for pain between cognitive load and moral decision-making.

Keywords Moral decision-making · Cognitive load · Empathy for pain · Virtual reality · Moral dilemmas

Introduction

Morality, as a core social ideology, provides fundamental guidelines and standards for human behavior and life. In daily life, individuals frequently face decisions that affect personal interests or the interests of others. Moral decision-making is a critical topic in human behavior research, focusing on decisions guided by moral norms or social values. At its core, it involves choosing between competing societal interests (Rilling & Sanfey, 2011). There is no consensus on the definition of moral decision-making. Early researchers, adopting a rationalist perspective, defined moral decision-making as identifying moral problems and acting within the constraints of social norms (Jones, 1991). In this view, moral decision-making is primarily driven by rational analysis. Later researchers described moral decision-making as a heuristic process involving rapid cognitive reasoning and moral judgments. This process includes complex cognitive activity while being influenced by unconscious factors, such as emotions, emphasizing their role in decision-making (Haidt, 2001). Recently, moral decision-making has been broadly defined as decisions within the "moral domain", encompassing judgments, evaluations, and responses. Moral decision-making entails weighing gains and losses between oneself and others in social decisions. When confronted with conflicting choices, individuals optimize decisions based on self-values within social norms (Rilling & Sanfey, 2011). During this process, decision-makers encounter strong negative emotions and cognitive conflicts while evaluating the pros and cons of their actions and outcomes (Pletti et al., 2015; Zhan et al., 2022). These decisions reflect both the moral value of behaviors and the moral responsibility of decision-makers, while also representing specific moral norms. Moral decision-making is crucial for human social life and underpins individual actions. Currently, researchers have expanded their focus to investigate specific cognitive, emotional, and situational variables in moral decision-making (Chen et al., 2023; Martinez et al., 2024; Schwartz et

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al., 2021, 2022; Vavra et al., 2024). This study examined the effects of cognitive load, empathy for pain, moral dilemma types (personal dilemma, impersonal dilemma), and information presentation modes (text, virtual reality) on moral decision-making.

Cognitive load

Cognitive load is a key cognitive factor influencing moral decision-making. Cognitive load refers to the cognitive resources required for processing information, solving problems, and making decisions (Barrouillet et al., 2007). The dual-process theory posits that moral decision-making is influenced by both a rapid, emotion-driven system and a slower, rational cognitive system, with the process of rational analysis requiring more cognitive resources (Awad et al., 2020). This suggests that when individuals are in a state of high cognitive load, they are less likely to make rational decisions. Individuals allocate cognitive resources to accomplish goal-directed tasks. As cognitive resources are finite, when a task consumes a substantial portion, the remaining capacity is insufficient for other tasks, thereby restricting cognitive processing (Giesbrecht et al., 2014; Yuan & Liu, 2021). Under these conditions, individuals are more inclined to depend on the emotional system, resulting in fewer utilitarian decisions.

Any activity an individual engages in, such as learning, attention, or problem-solving, consumes cognitive resources. Complex tasks consume more cognitive resources, leading to higher cognitive load. Studies have shown that individuals with higher cognitive demands tend to engage in more rational reasoning, often becoming more utilitarian (Bartels, 2008). Other research using process separation methods has found that cognitive load selectively reduces utilitarian tendencies without affecting deontological tendencies (Conway & Gawronski, 2013). These studies suggest that when additional factors in the environment increase cognitive load, individuals may find it difficult to focus more cognitive resources, and since utilitarian tendencies depend on cognitive resources, individuals are more likely to reduce utilitarian choices (Greene et al., 2001; Royzman et al., 2015).

Empathy for pain

Empathy for pain, a specific form of empathy, refers to the perception, judgment, and emotional response to another person's pain (Ren et al., 2022). Typically, people do not need to experience pain directly to understand others' suffering, imagining another' s pain can trigger empathy for pain (Jackson et al., 2006). For example, witnessing a friend cut their finger while slicing fruit may cause you to feel their pain—this is empathy for pain (Cheng & Huang, 2012). This response characterizes empathy (Singer et al., 2004). The principle of emotional contagion clarifies the mechanism behind emotional resonance. Emotions spread between individuals. When someone observes or interacts with a person in an intense emotional state, they may unconsciously mimic facial expressions, vocal tone, and posture, leading to a similar emotional experience (Hatfield et al., 1993). This mechanism explains why individuals quickly and unconsciously empathize with others' pain. This response exemplifies "automatic emotional processing" and demonstrates the role of the emotional system in dual-process theory. At the neuroscientific level, mirror neuron activity forms the biological basis for understanding empathy and emotional contagion. Observing others' pain activates mirror neurons (Du & Chen, 2024; Rizzolatti & Craighero, 2004). Emotional resonance with others may motivate individuals to alleviate others' pain or discomfort. This activates the anterior cingulate cortex and insula, brain regions associated with decision-making. According to the dual-process theory, moral decision-making relies not only on rational cognition but is also strongly driven by the emotional system (Awad et al., 2020). Emotional responses to others' pain drive individuals to act, reducing their own distress and promoting social harmony. This process ultimately fosters decisions that enhance societal well-being (Batson, 2014). Since utilitarianism seeks the greatest good for the greatest number, empathy for another's pain may increase the likelihood of utilitarian decisions.

The relationship between cognitive load and empathy for pain

In daily life, the brain continuously distributes cognitive resources across multiple tasks, and others' pain is often sudden and unpredictable, capturing our attention. According to the dual-process theory, moral decision-making involves both cognitive systems and emotional systems. The cognitive system depends on finite cognitive resources, whereas the emotional system reacts swiftly to external stimuli. When cognitive resources are significantly depleted, individuals tend to rely more on emotion-driven decision-making (Awad et al., 2020). Cognitive load leads individuals to overlook key information, reducing task performance (Gilbert et al., 1988). Finite cognitive resources constrain an individual's capacity to process information. As cognitive load increases, resources are predominantly directed toward the primary task, reducing the ability to suppress irrelevant stimuli (Holmes et al., 2014). It makes individuals more susceptible to interference from irrelevant stimuli. When empathy for pain, a complex emotional stimulus, is introduced into a high-load task, it further disturbs cognitive load. Research indicates that high cognitive load reduces individuals' willingness to care when listening to a crying baby, and empathy could mediate the effects of both (Hiraoka & Nomura, 2016). Intense empathy for others' suffering enhances prosocial motivation to maximize societal well-being (Gu et al., 2024). Empathy-driven care promotes altruistic motives aimed at enhancing others' well-being (Thomas et al., 2011), while utilitarianism similarly seeks to maximize societal benefit. Therefore, under high cognitive load, inducing empathy may encourage more utilitarian choices. Based on this, research hypotheses are proposed as follows:

H1a: High cognitive load reduces the likelihood of utilitarian decision-making.
H1b: Empathy for pain enhances the propensity for utilitarian decision-making.

Neural foundation of empathy for pain and cognitive load

Electroencephalogram (EEG) signals provide information into relaxation degree and mental effort. Increased relaxation degree is significantly linked to reduced brain activity, whereas mental effort quantifies an individual's cognitive workload. This enables the assessment of relaxation degree and mental effort under cognitive load in the context of empathy for pain, measurable via brain-computer interface (BCI) devices. Brain-computer interface (BCI) design is an emerging interdisciplinary field combining machine learning (ML) and human-computer interaction (HCI), with widespread applications. BCI systems rely on wearable devices to collect electroencephalogram (EEG) signals from the frontal lobe. Wearable devices are cross-subject and small-scale (Wu et al., 2022), offering convenience. The reliability of using brain waves to measure cognitive load is well-established (Dehais et al., 2018). Research has shown that the frontal lobe plays a crucial role in brain activity, closely associated with personality, emotional responses, attention, rational thinking, and creative performance. Recent brain imaging studies have found that moral decision-making activates brain regions involved in higher cognitive functions, including self-processing, emotional responses, and cognitive reasoning.

Psychologically, when individuals witness others' pain, they may experience emotional resonance, an unconscious, natural tendency to empathize (Du & Chen, 2024). Under high cognitive load, empathy for pain is automatically induced without requiring conscious control or effort (Preston & De Waal, 2002), This automatic emotional processing may reduce cognitive resources consumption, reducing mental effort and enhancing relaxation degree. This study employs a head-mounted electroencephalogram (EEG) device to measure brain activity under cognitive load and empathy for pain, focusing on physiological indicators like relaxation degree and mental effort, aims to examine the relaxation degree and mental effort during empathy for pain under high cognitive load.

Moral dilemma types

Moral dilemmas are a classic issue in moral psychology research (Klenk, 2022). Moral dilemmas provide the basis and context for moral decision-making, prompting individuals to apply moral principles to resolve conflicts (Yang & Shen, 2024). Typically, moral dilemmas are divided into personal and impersonal dilemmas. In personal dilemmas, such as the footbridge dilemma, utilitarian decision-making involves an individual directly causing harm, for example, pushing one person off a footbridge to save five others. The harm to the victim is directly inflicted by the individual. In impersonal dilemmas, such as the trolley problem, the individual switches the trolley's track, causing harm to one person in order to save five others. The dual-process theory suggests that moral decision-making is an integration of cognitive reasoning and emotional responses. In impersonal dilemmas, most people prefer utilitarian decisions, guided by controlled cognitive processes, reflecting thoughtful reasoning. In personal dilemmas, people tend to prefer deontological decisions, driven by automatic emotional responses (Awad et al., 2020). The utilitarian perspective holds that causing harm to a few individuals is morally acceptable to prevent greater harm to many. In contrast, deontological ethics asserts that individuals have inviolable rights and a duty to uphold moral principles, opposing harm even if it benefits more people (Liu & Liao, 2021).

Studies have shown that, the costs and benefits in both types of dilemmas are identical, most people find it morally more acceptable to switch the trolley's direction than to push a person off the bridge (Lin & Gao, 2020). Research suggests that variations in individuals' event construal levels affect their decision-making tendencies (Alper, 2020). Construal level is determined by psychological distance from the cognitive object, with shorter distances eliciting stronger emotional responses (VanHorn, 2020). Compared to impersonal dilemmas, individuals are closer to the cognitive object in personal dilemmas, and the presence of direct physical contact can trigger intense feelings of disgust. Such strong negative emotions lead individuals to avoid directly causing harm, thereby activating automatic intuitive processing (Conway & Gawronski, 2013). This emotional mechanism interferes with utilitarian judgment (Patil et al., 2021), reducing the likelihood of utilitarian decisions (Guan et al., 2017). In contrast, in impersonal dilemmas, individuals are more distant from the cognitive object, reducing emotional involvement and allowing rational thinking to guide decision-making for an optimal solution. Therefore, different dilemmas activate distinct decision systems, with the more activated system taking the dominant role.

Presentation modes

In recent years, the rapid development of virtual reality (VR) technology has increasingly been applied to moral decision-making research (Francis et al., 2016; Navarrete et al., 2012; Patil et al., 2014). Previous studies mainly used text-based presentations (Christensen & Gomila, 2012), while VR technology introduces new tools and methods for moral decision-making research. VR enables the construction of more complex and realistic moral scenarios, facilitating a deeper exploration of decision-making processes and influencing factors. However, differences in moral decision-making tendencies have been found between text-based and VR presentations (Francis et al., 2016; Patil et al., 2014). This does not determine whether the moral choices individuals make in textual materials accurately reflect their real-world actions.

VR technology provides an immersive environment that stimulates participants' sensory and emotional responses, making it easier for them to engage in specific situations. Moreover, in a VR environment, certain mediums are more likely to elicit empathy (Modena & Pinotti, 2020), depending on the materials and presentation methods used. However, the VR environment simply provides an environment conducive to empathy, and is not sufficient to directly trigger specific responses, such as empathy for pain. VR simulates moral conflicts in real-life scenarios, enabling precise control over experimental conditions and allowing researchers to observe behavioral responses in realistic situations, facilitating the collection of detailed behavioral data and physiological indicators, and objectively reflecting their reactions in the moral decision-making process, thus exploring its intrinsic mechanisms (He et al., 2018). Based on this, research hypotheses are proposed as follows:

H2: Presentation modes and moral dilemma types affect utilitarian decision-making.

In summary, it is currently unclear whether and how cognitive load and empathy for pain, as cognitive and emotional factors, affect moral decision-making. This study, based on the dual-process theory, theoretically integrates the mechanisms by which cognitive and emotional factors influence moral decision-making. The dual-process theory posits that moral decision-making results from the interaction between cognitive processing and emotional responses. In this context, cognitive load acts as a key factor in cognitive processing, directly affecting an individual's information processing ability, whereas empathy for pain, as an emotional factor, shapes moral perception and judgment. Furthermore, this study expands the dual-process theory by incorporating two dimensions: moral dilemma types (personal, impersonal) and information presentation modes (text, virtual reality). Specifically, moral dilemma types influence moral decision-making tendencies under cognitive load and empathy for pain. In personal dilemmas, emotional responses predominate, while cognitive processing is more influential in impersonal dilemmas. Additionally, the mode of information presentation (text, virtual reality) affects cognitive load and empathy for pain by modulating situational immersion and emotional arousal. Therefore, this study aims to explore the influence of cognitive load and empathy for pain on moral decision-making tendencies in moral dilemmas within VR and brain-computer interface (BCI) environments. Based on the dual-process theory, this study clarifies the interaction between cognitive and emotional factors in moral decision-making. This study is validated through two experiments. Experiment 1 aims to examine the influence of cognitive load on moral decision-making tendencies in different moral dilemmas under text and VR conditions. Experiment 2 aims to explore the roles of pain empathy and cognitive load in moral decision-making within moral dilemmas in VR and brain-machine environments, as well as the corresponding EEG responses. This study verifies and extends the dual-process theory, providing empirical evidence for future research.

Experiment 1: The influence of presentation modes and moral dilemma types on moral decision-making tendencies under cognitive load

Experiment 1 is grounded in the dual-process theory, which suggests that "cognition" plays a key role in moral decision-making. Previous research has found that presentation modes and the types of moral dilemma have different effects on moral decision-making (Francis et al., 2016). Experiment 1 aims to examine the influence of cognitive load on moral decision-making tendencies in different moral dilemmas under text and VR conditions. This experiment tests H1a and H2.

Methods

Transparency and openness

We report how we determined the sample size, all data exclusions (if any), all operations, and all measures used in the study. To ensure scientific rigor, methodological integrity, accuracy, and clarity, we followed the latest standards for research reporting in the Journal Article Reporting Standards (JARS) (Kazak, 2018). All data are publicly available on OSF and can be accessed at https://osf.io/j3znq/?view_only=acbb84b3cc054a688db1482e9da403c8. The data were analyzed using SPSS (Version 25). The design and analysis of this study were not preregistered.

Ethics approval statements

This study was approved by the first author's institution for ethical review, and complied with the provisions of the World Medical Association Code of Ethics (Declaration of Helsinki) concerning experiments involving humans. Due to different institutional policies, there was no approval number. Participants volunteered to participate in the experiment and signed a paper version of the experimental informed consent. Prior to the start of the experiment, the procedure, purpose, and duration of the experiment were explained, and participants were informed that they could withdraw from the experiment at any time, without any potential risk, and that their privacy would always be respected.

Participants

College students were recruited as participants for this experiment. The sample size was calculated using G*Power 3.1 software (Faul et al., 2007), with an effect size of 0.25, significance level of 0.05, and statistical power of 0.80. The minimum calculated sample size was 48 participants. In practice, 60 college students participated in the experiment (48 females, mean age 20.13 ± 1.44 years; 12 males, mean age 20.00 ± 1.28 years). Participants were randomly assigned to four experimental groups, with 15 participants per group. Participants were randomly assigned to four experimental groups, with 15 participants per group. Informed consent was obtained before the experiment, and participants were compensated after its completion.

Experimental design

A 2 (cognitive load: high-load, low-load) × 2 (presentation modes: text, VR) × 2 (moral dilemmas: personal dilemma, impersonal dilemma) mixed experimental design was adopted. Cognitive load and presentation modes were between-subject variables, while moral dilemmas was a within-subject variable. The dependent variable was the score of the utilitarian choices made by the participants.

Experimental tasks and equipment

The experimental tasks were presented on a 24-inch LED monitor with a resolution of 1920×1080 and a vertical refresh rate of 60 Hz. The distance between the participant and the monitor was approximately 70 centimeters.

Manipulation of cognitive load Under the high cognitive load condition, participants need to memorize a 6-digit string; under the low cognitive load condition, participants need to memorize a 2-digit string. The strings in the experiment are randomly generated by the E-prime 2.0 program, with a total of 120 strings of 2-digit and 6-digit numbers to be memorized (Cheng et al., 2017). Participants' memory string accuracy and response times were recorded during the cognitive load task to assess the effect of cognitive load.

Moral dilemmas

Impersonal dilemma The trolley dilemma. In the model, a trolley is heading towards five workers, and there is one person on the branching track. Participants need to decide whether to switch the trolley to sacrifice one person to save five people. Choosing to sacrifice one person to save five is considered utilitarian, otherwise, it is considered deontological (Greene, 2007).

Personal dilemma The footbridge dilemma. A trolley is heading towards five workers, and the participant must decide whether to push a man off the footbridge above the trolley to save the five workers. Pushing the man off is a utilitarian choice, sacrificing one person to save five; not pushing the man off is a deontological choice.

Presentation modes

Text materials Presented by the computer program E-prime 2.0, the instructions, problem materials, questions, and options were presented in sequence, and participants were required to make their choices by pressing keys. The text materials included scenarios and questions from both personal dilemmas (the footbridge dilemma) and impersonal dilemmas (the trolley dilemma). The questions measured the utilitarian choice scores. In the impersonal dilemma, participants were asked, "To what extent would you switch the trolley track to save the five workers?" In the personal dilemma, participants were asked, "To what extent would you push the large man beside you to save the five workers?" Participants could choose from four options: "definitely not", "probably not", "probably yes", and "definitely yes", with corresponding scores of 0, 0.25, 0.75, and 1, respectively. Higher scores indicated a stronger utilitarian tendency (Bartels, 2008). The text was limited to 175–195 words, formatted in a small, four-point Song font with black characters on a white background.

Virtual reality Using 3D MAX software, we independently created VR models for the trolley problem (personal dilemma) and the footbridge dilemma (impersonal dilemma). The scene includes virtual characters for the victims and those to be saved, but no virtual body for the participant. The decision-making questions are consistent with the text materials, and the moral dilemmas is explained to the participants through voice-guided instructions in the VR environment. The experimental tools include the ErgoVR device and Vizard software, with participants wearing virtual reality headsets and using controllers to navigate and manipulate the scene. The scene model created with 3D MAX software was converted to OSGB format files, imported into the Vizard Inspector module for editing, and paired with Python code and voice instructions. The scene model was then projected onto two projection walls to generate the virtual reality environment.

Experimental procedure

Participants were randomly assigned to four groups: high cognitive load text presentation, high cognitive load VR presentation, low cognitive load text presentation, and low cognitive load VR presentation. The experiment was conducted in a comfortable environment. Participants first performed a cognitive load task. In the high cognitive load group, participants saw a 6-digit string, while those in the low cognitive load group saw a 2-digit string. Participants had to select the string that matched the previously shown one from two options presented afterward. If the left string matched, they pressed the "F"; if the right string matched, they pressed the "J". This task increased cognitive load. Participants' memory string accuracy and response times were recorded during the cognitive load task to assess the effect of cognitive load. After the completion of the task, each subject was guaranteed to start the moral dilemmas decision-making task within 1 min under the timing, and there would be no time delay between the two tasks. In the text presentation condition, participants within 1 min under the timing proceeded to the moral dilemmas task using the E-prime 2.0 program after completing the cognitive load task. Participants read the text materials and questions and selected one of four options in response. In the VR presentation condition, participants wore VR headsets and used practice controllers to navigate the scene within 1 min after completing the cognitive load task. In the VR scene, they saw a 3D depiction of the sky, trolley, tracks, footbridge, five workers in distress, the worker who was about to be sacrificed, and the green space, all highly realistic. Participants also heard voice-guided instructions describing the moral dilemmas scenario and questions, consistent with the text condition. Participants spoke their choice, and the main experimenter recorded their responses using the E-prime 2.0 program, under the supervision of the assistant. Afterward, participants were informed that the scenario was not real and that there was no psychological pressure.

Results

SPSS 25.0 software was used to analyze the data by *t* test and repeated measures analysis of variance.

Results of cognitive load manipulation test

An independent sample *t*-test was conducted on the correct rate and reaction time of the two cognitive load levels. Regarding the correct rate, the high-load group (M=98.06, SD=2.18) performed worse than the low-load group (M=99.50, SD=0.92, $t_{(58)}=-3.34$, $p<0.01$, Cohen's d=0.86). Regarding reaction time, the high-load group (M=1433.81, SD=507.00) had significantly longer reaction times than the low-load group (M=647.69, SD=128.53, $t_{(58)}=8.23$, $p<0.001$, Cohen's d=2.13), indicating that the two cognitive load levels were effective.

Moral decision-making results

A repeated measures ANOVA with a 2 (cognitive load: high-load, low-load) × 2 (presentation: text, VR) × 2 (moral dilemmas: personal dilemma, impersonal dilemma) design was conducted, using utilitarian choice scores as the dependent variable. The results showed a significant main effect of cognitive load ($F_{(1,56)}=6.46$, $p<0.05$, $\eta_p^2 = 0.10$). Post hoc *t*-tests with Bonferroni correction showed that participants in the high load group had significantly lower utilitarian choice scores (0.20 ± 0.04) compared to those in the low load group (0.33 ± 0.04, $p < 0.05$). The main effect of presentation modes was also significant ($F_{(1,56)}$ = 12.21, $p<0.01$, $\eta_p^2 = 0.18$). Post hoc *t*-tests with Bonferroni correction showed that participants in the VR condition had significantly higher utilitarian choice scores (0.36 ± 0.04) compared to those in the text condition (0.18 ± 0.04, $p < 0.01$). A significant main effect of moral dilemmas was found ($F_{(1,56)} = 52.90$, $p<0.001$, $\eta_p^2 = 0.49$). Post hoc *t*-tests with Bonferroni correction showed that participants had significantly higher utilitarian choice scores in the impersonal dilemma (0.36 ± 0.03) compared to the personal dilemma (0.17 ± 0.03, $p < 0.001$).

The interaction between moral dilemmas and presentation modes was significant ($F_{(1, 56)}=4.90$, $p<0.05$, $\eta_p^2 = 0.08$). Further simple effect tests found that in the impersonal dilemma of VR, the utilitarian choice score of the subjects (0.48 ± 0.05) was significantly higher than that of the subjects under the text presentation modes (0.24 ± 0.05, $p < 0.01$). In the personal dilemma of VR, the utilitarian choice score (0.23 ± 0.04) was significantly higher than that of text presentation (0.11 ± 0.04, $p < 0.05$) (Fig. 1).

The interaction between cognitive load and presentation modes was marginally significant ($F_{(1, 56)}=3.63$, $p=0.06$, $\eta_p^2 = 0.06$). Further simple effect tests showed that (Fig. 2), in the VR presentation modes, the utilitarian selection score of the high-load group (0.24 ± 0.05) was significantly lower than that of the low-load group (0.48 ± 0.05, $p < 0.01$). In the text presentation modes, there was no significant difference in the scores between the high-load group (0.16 ± 0.05) and the low-load group (0.19 ± 0.05, $p > 0.05$). Descriptive statistics are shown in Table 1.

Discussion

Experiment 1 compared text and VR presentation modes and found that presentation modes, moral dilemma types, and cognitive load all influence moral decision-making tendencies. In the VR condition, individuals tended to make utilitarian choices in both impersonal and personal dilemmas. This may be due to the VR environment's ability to trigger greater emotional arousal and empathy (Modena & Pinotti, 2020). Research has shown that VR environments are more realistic than traditional settings, stimulating sensory, emotional, and cognitive responses (He et al., 2018). This immersion allows individuals to engage more deeply with the characters and events in the virtual scenario. VR creates an environment conducive to empathy, enabling individuals to perceive the realism and emotional resonance of moral dilemmas, thus facilitating utilitarian decision-making.

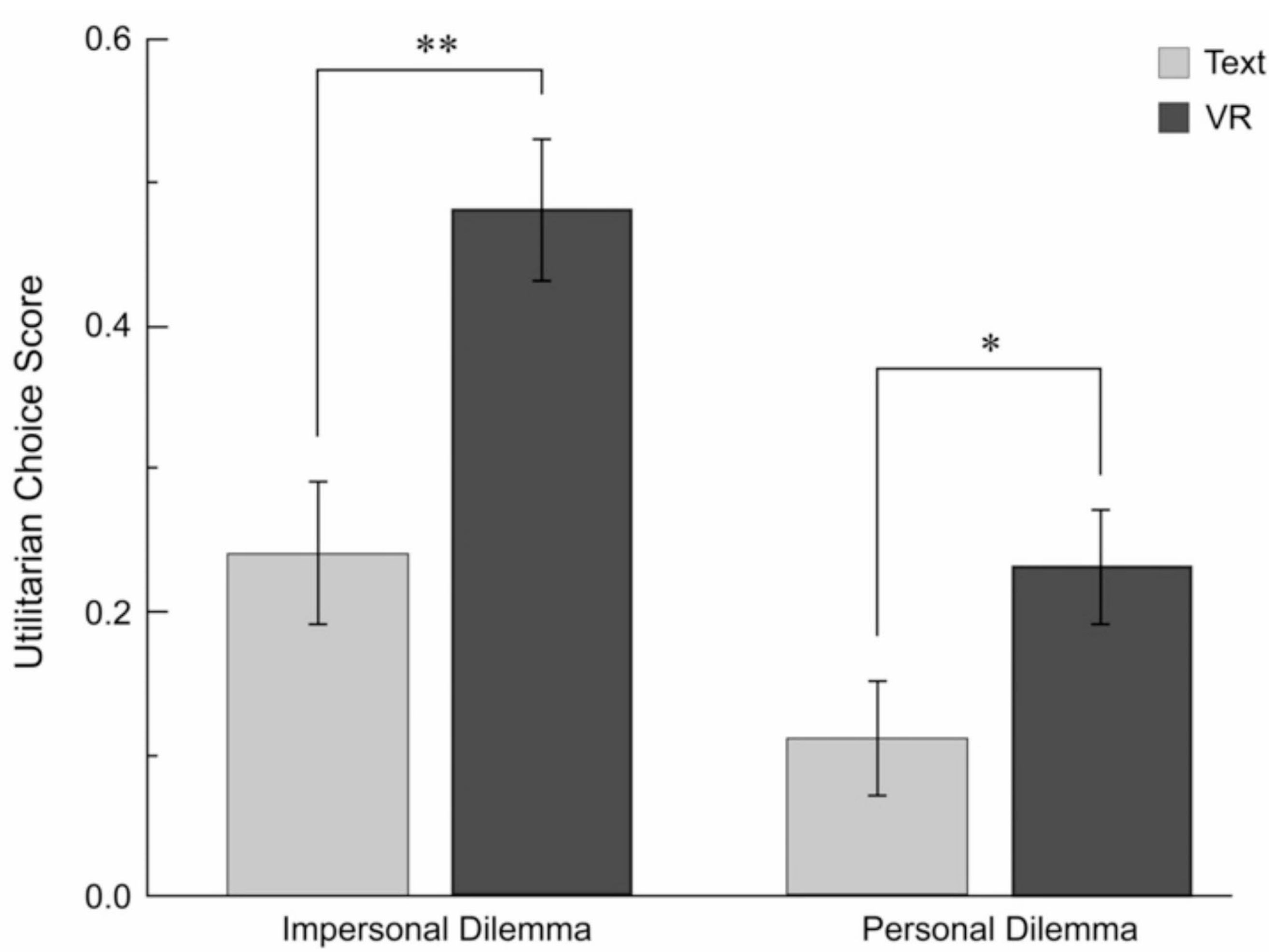

Fig. 1 Utilitarian choice scores of individuals in different types of moral dilemmas under different presentation modes(M±SE). *Note*: Error bars represent standard error, $^{**}p<0.01$, $^{*}p<0.05$

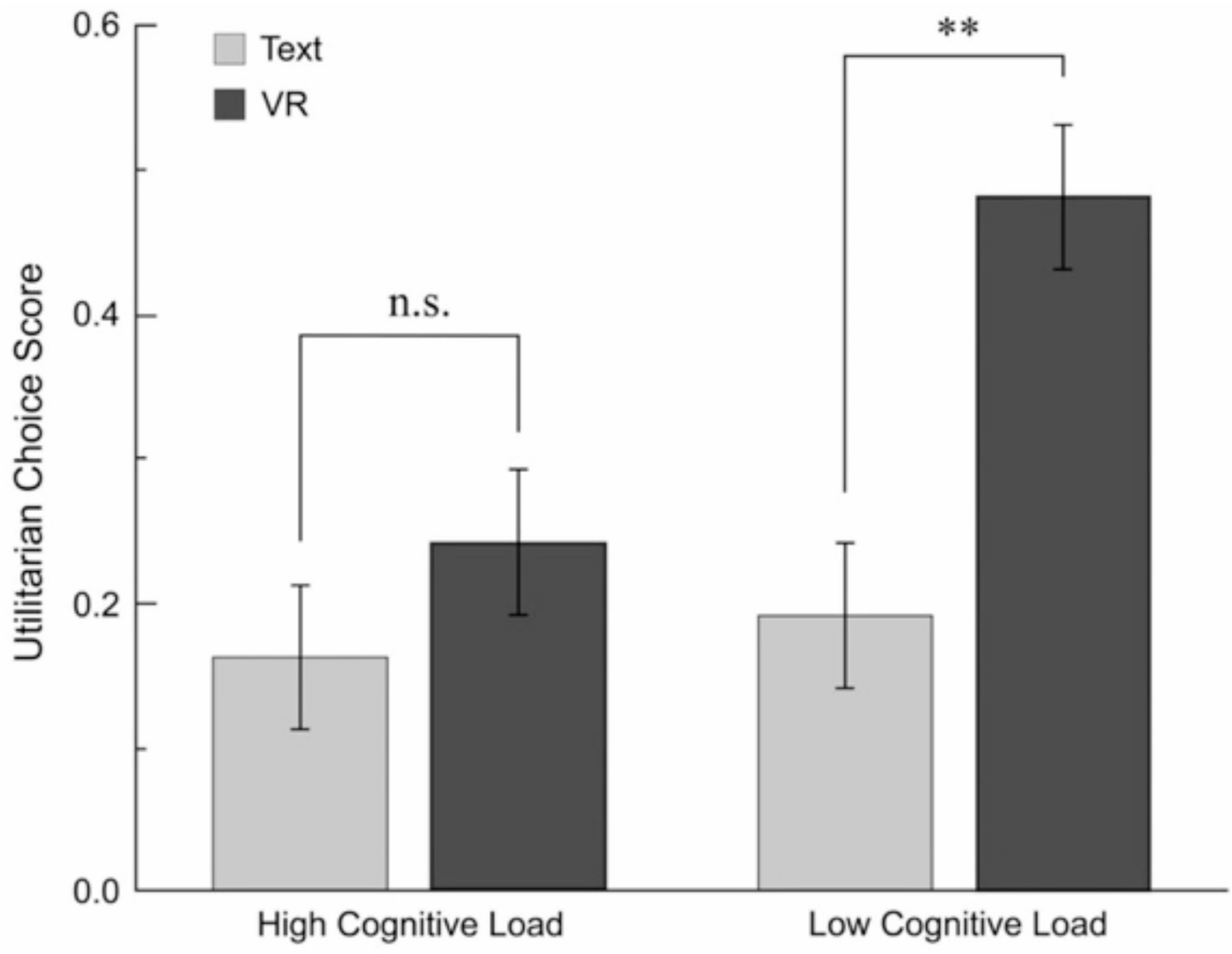

Fig. 2 Utilitarian choice scores of individuals in different types of moral dilemmas under different presentation modes ($M \pm SE$). *Note*: Error bars represent standard error, $^{**}p<0.01$, n.s. indicates no significant difference

Table 1 Descriptive statistics of moral decision-making scores under different moral dilemmas, cognitive loads and presentation modes ($M \pm SD$)

Moral dilemmas	Cognitive load	Presentation modes	*M*	*SD*
Impersonal Dilemma	Low Load	Text	0.27	0.22
		VR	0.60	0.31
	High Load	Text	0.22	0.19
		VR	0.37	0.30
Personal Dilemma	Low Load	Text	0.12	0.13
		VR	0.35	0.31
	High Load	Text	0.10	0.13
		VR	0.12	0.13

The experiment found that individuals under high cognitive load tended to make fewer utilitarian choices, while no significant difference was observed in the text presentation condition. Under high cognitive load, individuals often experience substantial psychological stress and cognitive burden. This state requires individuals to process large amounts of information while coping with the emotional pressure it generates. As a result, individuals facing moral dilemmas are more likely to adhere to established moral norms. Additionally, high cognitive load may enhance individuals' moral sensitivity. This increased moral sensitivity may prompt individuals to make fewer utilitarian choices in VR-based moral dilemmas.

Additionally, according to the dual-process theory, emotional factors play a crucial role in moral decision-making. Research suggests that empathy for pain can modulate the influence of cognitive load on moral decision-making tendencies (Hiraoka & Nomura, 2016). Investigating empathy for pain is thus of significant research value. Experiment 1 demonstrated that VR enhanced emotional resonance in participants, eliciting genuine emotional responses. It enhanced interactivity and autonomy while improving the external validity of the study. Experiment 2 thus included the measurement of physiological data in the VR environment to explore the effects of moral dilemma types, cognitive load, and empathy for pain on moral decision-making tendencies, and the role of induced empathy for pain in greater depth.

Experiment 2: The influence of cognitive load on moral decision-making tendencies in moral dilemmas under a virtual reality environment: the role of empathy for pain

Based on the results of Experiment 1, significant differences were found between presentation modes, and cognitive load independently influenced moral decision tendencies. According to the dual-process theory, Experiment 2 examined whether cognitive and emotional factors could simultaneously influence moral decision-making, whether there was an interaction effect, and whether it could provide a research basis for the theoretical model. Previous studies have predominantly examined behavioral and event-related potential (ERP) responses. This experiment adopted a novel physiological measurement approach, utilizing brain-computer interface (BCI) devices for data collection. Therefore, Experiment 2 monitored brain waves in the VR environment and BrainLink Pro environment to examine individuals' relaxation degree and mental effort under cognitive load and empathy for pain, as well as to investigate the role of empathy for pain in the influence of cognitive load on moral decision-making. This experiment tests H1b.

Methods

Transparency and openness

We report how we determined the sample size, all data exclusions (if any), all operations, and all measures used in the study. To ensure scientific rigor, methodological integrity, accuracy, and clarity, we followed the latest standards for research reporting in the Journal Article Reporting Standards (JARS) (Kazak, 2018). All data are publicly available on OSF and can be accessed at https://osf.io/j3znq/?view_only=acbb84b3cc054a688db1482e9da403c8. The data were analyzed using SPSS (Version 25). The design and analysis of this study were not preregistered.

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Participants

College students were recruited as participants for this experiment. The sample size was determined using G*power 3.1 software (Faul et al., 2007), with an effect size of 0.25, a significance level of 0.05, and a statistical power of 0.80. The calculated minimum sample size was 48 participants. In practice, 60 students participated in the experiment (46 females, mean age 19.50 ± 1.35 years; 14 males, mean age 19.93 ± 1.49 years). Participants were randomly assigned to four experimental groups, with 15 participants per group. All participants had normal vision, were right-handed, and had no history of color blindness or mental illness. The participants in this experiment were distinct from those in Experiment 1, with no overlap between the groups. Informed consent was obtained prior to the experiment, and participants were compensated after its completion.

Experimental design

A 2 (cognitive load: high-load, low-load) × 2 (empathy for pain: pain images, non-pain images) × 2 (moral dilemmas: personal dilemma, impersonal dilemma) mixed experimental design was adopted. Cognitive load and empathy for pain were between-subject variables, while type of moral dilemmas was a within-subject variable. The dependent variable was the score of the utilitarian choices made by the participants.

Experimental stimuli and equipment

The experimental tasks were presented on a 24-inch LED monitor with a resolution of 1920×1080 and a vertical refresh rate of 60 Hz. The distance between the participant and the monitor was approximately 70 centimeters.

Experimental manipulation The manipulation of cognitive load follows the same procedure as in Experiment 1. The moral dilemmas materials consist of the VR version of the scene model, using the same scenarios as in Experiment 1. The VR equipment is the same as in Experiment 1. Empathy for pain is manipulated using audio and images as stimuli (Meng et al., 2012, 2013). The audio includes pain and neutral sounds, while the images depict common daily life scenarios, each paired with a non-pain counterpart. Each category contains 60 images, all of the same size. During the experiment, both audio and images are presented simultaneously: pain audio is paired with pain images, and neutral audio with non-pain images. Both the audio and images are presented randomly, each twice. After the task, the validity of the stimuli is assessed using four questions: pain intensity (1 = no sensation, 9 = severe pain), affective valence (1 = very unhappy, 9 = very happy), arousal (1 = very calm, 9 = very excited), and dominance (1 = completely controllable, 9 = completely uncontrollable) (Meng et al., 2024). The empathy for pain scale is then measured with five questions assessing whether participants perceive the protagonist in the images and audio as unfortunate, miserable, pitiable, sympathetic, or compassionate, using a 7-point rating (1 = not at all, 7 = very strongly). Higher scores indicate greater levels of empathy for pain (Greitemeyer, 2013) and are used to assess differences in empathy for pain manipulation between the two participant groups.

Physiological equipment The BrainLink system, based on brain-computer interface technology, utilizes BrainLink Pro (Macrotellect Ltd., Shenzhen, China), a wearable device designed to record various electroencephalogram (EEG) signals (Wu et al., 2022). This device is a simplified EEG machine that achieves high wave recognition accuracy in a short time (Tsai et al., 2020). It contains specially designed electronic circuits that detect brain signals, filter out noise and muscle movement, and convert them into digital energy. The EEG sensors are integrated into a headband with three dry electrodes: EEG (signal channels), REF (reference point), and GND (ground). EEG signals are collected from the frontal lobe electrode point FPI (Girardi et al., 2017) and transmitted via Bluetooth to corresponding mobile device software. The device has a sampling frequency of 512 Hz, an electrode position at FP1, and a transmission range of up to 10 m (Tsai et al., 2020). The device provides real-time EEG spectrum information (e.g., Alpha, Beta, Theta waves) and advanced cognitive metrics (e.g., attention, relaxation degree, and mental effort) via built-in algorithms. These metrics are widely used in cognitive research, with accuracy comparable to that of traditional multi-electrode EEG systems (Niso et al., 2023).

In this experiment, the primary physiological indicators being examined are relaxation degree and mental effort. Relaxation degree is automatically derived by the algorithm based on the brainwave characteristics of a relaxed state, with values ranging from 0 to 100. A higher average score indicates a more relaxed brain or a deeper initial meditation state. The relaxation degree reflects an individual's mental state, with increased relaxation correlating with reduced brain activity. Mental effort can be used to measure how well an individual is using their brain. The value range is from −100 to 100, with data generated every 3–5 s. A higher value indicates a higher brain workload.

Interpersonal response indicator questionnaire The scale was revised by the Chinese version of Davis (1983) Interpersonal Response Indicator Questionnaire. It is divided into four dimensions, with a total of 22 items, and the scoring method is 5 points. In this study, the α coefficient is 0.78.

Experimental procedure

Firstly, participants will be randomly assigned to one of four groups: high cognitive load pain image, high cognitive load non-pain image, low cognitive load pain image, or low cognitive load non-pain image. The experiment was conducted in a comfortable environment. Secondly, before the experiment begins, participants are required to complete the Interpersonal Reactivity Index as a control variable to ensure that the empathy levels of participants in the two groups are equivalent before the manipulation of empathy for pain. At the start of the experiment, the BrainLink Pro device, worn on the participant's forehead, ensures close contact between the electrodes and skin, and an ear clip is attached to the left earlobe. If the device fails to collect EEG data or receives poor signals, it will issue a warning to adjust the sensors. Participants then complete the cognitive load task: the high cognitive load group remembers a 6-digit string, while the low cognitive load group remembers a 2-digit string. In the pain image group, both pain images and audio are presented simultaneously, while the non-pain image group receives non-pain images and audio. Participants passively view the images and listen to the audio, then select the string that matches their previous memory from two sets of strings presented afterward. If the left string matches the previous memory, participants press the "F"; if the right string matches, they press the "J". Participants' memory string accuracy and response times were recorded during the cognitive load task to assess the effect of cognitive load. The experiment consists of 4 blocks, each with 60 trials. The 4 conditions are randomly presented, with each appearing equally, for a total of 240 trials. Each image appears twice. After completing the task, participants are asked to rate the pain intensity, affective valence, arousal, and dominance of the images and fill out the empathy for pain scale. After the completion of the task, each subject was guaranteed to start the moral dilemmas decision-making task within 1 min under the timing, and there would be no time delay between the two tasks. In the VR moral dilemmas task, the two scenarios are the same as in experiment 1. Voice instructions describe the dilemma scenario and response options, and participants respond orally. Under the supervision of the experiment assistant, the experimenter records responses using E-prime 2.0 software. At the end of the experiment, participants are informed that the scenario is not real and that no psychological stress is required.

Results

SPSS 25.0 software was used to analyze the data by t test and repeated measures analysis of variance.

Cognitive load and empathy for pain manipulation test results

Correct rate results A two-way between-subjects analysis of variance (ANOVA) was conducted with cognitive load and empathy for pain accuracy as the dependent variables, using a 2 (cognitive load: high-load, low-load) × 2 (empathy for pain: pain images, non-pain images) design. The results showed a significant main effect of cognitive load ($F_{(1, 56)}=16.66$, $p<0.001$, $\eta_p^2 = 0.23$). Post-hoc *t*-tests with Bonferroni correction showed that participants in the high-load group (96.47 ± 0.47) had significantly lower accuracy than those in the low-load group (99.17 ± 0.47, $p < 0.001$). The main effect of empathy for pain was also significant ($F_{(1, 56)} = 8.42$, $p<0.01$, $\eta_p^2 = 0.13$). Post-hoc *t*-tests with Bonferroni correction showed that participants in the empathy for pain group (96.86 ± 0.47) had significantly lower accuracy than those in the empathy for empathy for non-pain group (98.78 ± 0.47, $p < 0.01$). The interaction between cognitive load and empathy for pain was significant ($F_{(1, 56)} = 4.98$, $p<0.05$, $\eta_p^2 = 0.08$). Further simple effects analysis revealed that under empathy for pain, the accuracy of the high-load group (94.78 ± 0.66) was significantly lower than that of the low-load group (98.95 ± 0.66, $p < 0.001$). Under empathy for non-pain, there was no significant difference in accuracy between the high-load group (98.17 ± 0.66) and the low-load group (99.39 ± 0.66, $p > 0.05$).

Reaction time results A two-way between-subjects analysis of variance (ANOVA) was conducted with reaction time as the dependent variable, using a 2 (cognitive load: high-load, low-load) × 2 (empathy for pain: pain images, non-pain images) design. The results indicated a significant main effect of cognitive load ($F_{(1, 56)}=86.67$, $p<0.001$, $\eta_p^2 = 0.61$). Post-hoc *t*-tests with Bonferroni correction showed that participants in the high-load group (1735.68 ± 76.82) had significantly longer reaction times than those in the low-load group (724.25 ± 76.82, $p < 0.001$). The main effect of empathy for pain was marginally significant ($F_{(1, 56)} = 3.11$, $p = 0.08$, $\eta_p^2 = 0.05$). Post-hoc *t*-tests with Bonferroni correction showed that participants in the empathy for pain group (1325.82 ± 76.82) had marginally longer reaction times than those in the empathy for non-pain group (1134.11 ± 76.82, $p = 0.083$). The interaction between cognitive load and empathy for pain was marginally significant ($F_{(1, 56)} = 3.23$, $p=0.07$, $\eta_p^2 = 0.06$). Further simple effects analysis revealed that under empathy for pain, the reaction time of participants in the high-load group (1929.13 ± 108.64) was significantly longer than that of the low-load group (722.52 ± 108.64, $p < 0.001$). Under empathy for non-pain, the reaction time of participants in the high-load group (1542.22 ± 108.64) was significantly longer than that of the low-load group (725.99 ± 108.64, $p<0.001$). These results suggested that the manipulations of cognitive load and empathy for pain were effective.

Empathy for pain manipulation test Independent sample *t*-tests were conducted on the pain intensity, affective valence, arousal, and dominance scores of the pain images. The results showed a significant difference in pain intensity between the empathy for pain group ($M=5.80$, $SD=1.13$) and the empathy for non-pain group ($M=1.73$, $SD=0.58$, $t_{(58)}=17.56$, $p<0.001$). In terms of affective valence, there was a significant difference between the empathy for pain group ($M=3.53$, $SD=1.14$) and the empathy for non-pain group ($M=5.00$, $SD=0.83$, $t_{(58)} = -5.71$, $p<0.001$). Similarly, arousal showed a significant difference between the empathy for pain group ($M=3.90$, $SD=1.13$) and the empathy for non-pain group ($M=2.97$, $SD=1.35$, $t_{(58)}=2.68$, $p=0.01$). For dominance, the empathy for pain group ($M=6.27$, $SD=1.68$) showed significantly higher scores compared to the empathy for non-pain group ($M=5.23$, $SD=1.61$, $t_{(58)}=2.43$, $p<0.05$). An independent sample *t*-test on the total score of the empathy for pain scale revealed a significant difference between the empathy for pain group ($M=22.70$, $SD=3.98$) and the empathy for non-pain group ($M=7.97$, $SD=1.56$, $t_{(58)}=18.89$, $p<0.001$). These results indicated that the manipulation of empathy for pain was effective.

Control of additional variables

The independent sample *t*-test of the total score of the interpersonal response indicator scale showed that there was no significant difference in the total score of the scale between the high-load group ($M=78.50$, $SD=10.85$) and the low-load group ($M=77.30$, $SD=6.01$, $p>0.05$). There was no significant difference in the total score of the scale between the empathy for pain group ($M=79.37$, $SD=10.21$) and the empathy for non-pain group ($M=76.43$, $SD=6.78$, $p>0.05$).

The above results indicated that the group of subjects was not affected by empathy.

Physiological data

Relaxation degree results A two-way between-subjects analysis of variance (ANOVA) was conducted with the relaxation degree as the dependent variable, using a 2 (cognitive load: high-load, low-load) × 2 (empathy for pain: pain Images, non-pain Images) design. The results showed that the main effect of cognitive load was marginally significant ($F_{(1, 56)}$=3.62, p=0.06, η_p^2 = 0.06). Post-hoc *t*-tests with Bonferroni correction showed that the relaxation degree of the high-load group (53.93 ± 0.66) was higher than that of the low-load group (52.15 ± 0.66, p = 0.062). The interaction between cognitive load and empathy for pain was significant ($F_{(1, 56)}$ = 5.02, $p < 0.05$, η_p^2 = 0.08). Further simple effects analysis showed that under the empathy for pain condition, the relaxation degree of the high-load group (55.01 ± 0.94) was significantly higher than that of the low-load group (51.12 ± 0.94, $p < 0.01$). Under the empathy for non-pain condition, there was no significant difference in the relaxation degree between the high-load group (52.86 ± 0.94) and the low-load group (53.17 ± 0.94, $p > 0.05$).

Mental effort results A two-way between-subjects analysis of variance (ANOVA) was conducted with the cognitive load and mental effort index as the dependent variable, using a 2 (cognitive load: high-load, low-load) × 2 (empathy for pain: pain images, non-pain images) design. The results showed that the main effect of empathy for pain was significant ($F_{(1, 56)}$=8.13, $p<0.01$, η_p^2 = 0.13). Post-hoc *t*-tests with Bonferroni correction showed that the mental effort index of the empathy for pain group (−4.35 ± 4.30) was significantly lower than that of the empathy for non-pain group (12.98 ± 4.30, $p < 0.01$). The interaction between cognitive load and empathy for pain was significant ($F_{(1, 56)}$ = 5.03, $p<0.05$, η_p^2 = 0.08). Further simple effects analysis showed that under the high-load condition, the mental effort index of the empathy for pain group (−10.94 ± 6.08) was significantly lower than that of the empathy for non-pain group (20.12 ± 6.08, $p < 0.01$). Under the low-load condition, there was no significant difference in the mental effort index between the empathy for pain group (2.25 ± 6.08) and the empathy for non-pain group (5.94 ± 6.08, $p > 0.05$).

Moral decision-making results

A repeated measures analysis of variance (ANOVA) was conducted with utilitarian choice scores in moral decision-making as the dependent variable, using a 2 (cognitive load: high-load, low- load) × 2 (empathy for pain: pain images, non-pain images) × 2 (moral dilemmas: personal dilemma, impersonal dilemma) design. The results showed a significant main effect of empathy for pain ($F_{(1, 56)}$=10.43, $p<0.01$, η_p^2 = 0.16). Post-hoc *t*-tests with Bonferroni correction showed that the utilitarian choice scores of participants in the empathy for pain group (0.40 ± 0.04) were significantly higher than those in the empathy for non-pain group (0.20 ± 0.04, $p < 0.01$). The main effect of moral dilemmas was also significant ($F_{(1, 56)}$ = 15.60, $p<0.001$, η_p^2 = 0.22). Post-hoc *t*-tests with Bonferroni correction showed that participants' utilitarian choice scores in the impersonal dilemma (0.38 ± 0.04) were significantly higher than those in the personal dilemma (0.22 ± 0.03, $p < 0.001$).

The interaction between moral dilemmas and empathy for pain was significant ($F_{(1, 56)}$=4.32, $p<0.05$, η_p^2 = 0.07). Further simple effect tests showed that in the impersonal dilemma, the utilitarian choice score of the empathy for pain group (0.52 ± 0.06) was significantly higher than that of the empathy for non-pain group (0.23 ± 0.06, $p < 0.01$) (Fig. 3). In the personal dilemma, there was no significant difference in the scores of the empathy for pain group (0.28 ± 0.05) and the empathy for non-pain group (0.16 ± 0.05, $p > 0.05$).

The interaction between cognitive load and empathy for pain was significant ($F_{(1, 56)}$=4.08, $p<0.05$, η_p^2 = 0.07). Further simple effect tests showed that under high-load level, the utilitarian choice score of the empathy for pain group (0.48 ± 0.06) was significantly higher than that of the empathy for non-pain group (0.16 ± 0.06, $p < 0.001$) (Fig. 4). At the low-load level, there was no significant difference in the utilitarian choice scores between the empathy for pain group (0.31 ± 0.06) and the empathy for non-pain group (0.23 ± 0.06, $p > 0.05$). Descriptive statistics were shown in Table 2.

Discussion

Experiment 2 further investigated the influence of moral dilemma types, cognitive load, and empathy for pain on moral decision-making tendencies in VR and BrainLink Pro environments. The results showed an interaction between cognitive load and empathy for pain. Specifically, physiological data showed that individuals with high cognitive load exhibited greater relaxation degree and reduced mental effort when experiencing empathy for pain. However, at the empathy for non-pain level, this difference was not significant. This may be because empathy for pain activates emotional homeostasis mechanisms, but sustained empathy under high cognitive load may result in emotional burden. To mitigate this burden, individuals increase relaxation degree, maintain psychological balance, and process complex tasks

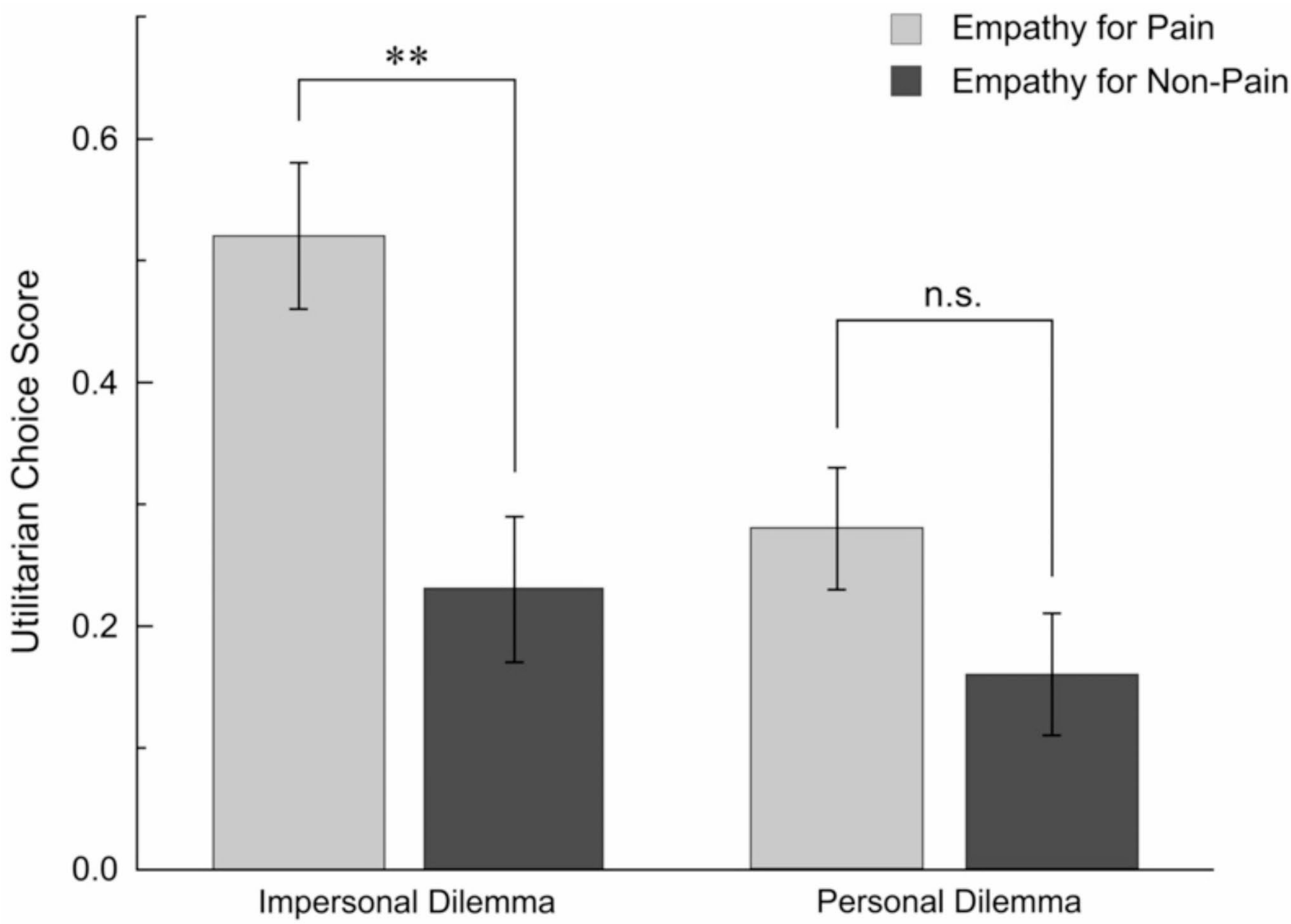

Fig. 3 Utilitarian choice scores of individuals in different types of moral dilemmas under different levels of empathy for pain ($M \pm SE$). *Note*: Error bars represent standard error, $^{**}p < 0.01$, n.s. indicates no significant difference

more effectively. Under resource constraints, the reduction in mental effort associated with high cognitive load reflects an optimization strategy employed by individuals (Preston & De Waal, 2002).

According to Load Theory, high cognitive load depletes cognitive resources for information processing, impairing the suppression of distracting stimuli (Holmes et al., 2014). Under normal conditions, individuals with high cognitive load typically feel less relaxed and show higher mental effort. However, when empathy for pain acts as a distractor under high cognitive load, it may reduce the tension and mental strain imposed by the load, potentially improving relaxation and brain activity. Furthermore, in high-stress environments or when cognitive resources are limited, individuals may adopt avoidance strategies (Gelfand et al., 2011). Viewing highly painful images may lead to emotional numbness, reducing brain activity and increasing relaxation under cognitive load.

The results also showed that, in impersonal dilemmas under VR conditions, individuals experiencing empathy for pain were more likely to make utilitarian choices. However, this difference was not significant in personal dilemmas. Under high cognitive load, individuals experiencing empathy for pain were more likely to make utilitarian choices, whereas no significant difference was observed under low cognitive load. This may occur because empathy for pain enables individuals to more deeply experience others' suffering, motivating them to reduce overall suffering or increase well-being (Singer et al., 2004). In impersonal dilemmas, where there is no direct personal involvement, individuals are more inclined to make decisions based on the overall social value. Furthermore, under high cognitive load, individuals have limited cognitive resources that need to be allocated efficiently to handle the current task. Empathy for pain can assist individuals in optimizing resource allocation, allowing them to make optimal decisions under time constraints.

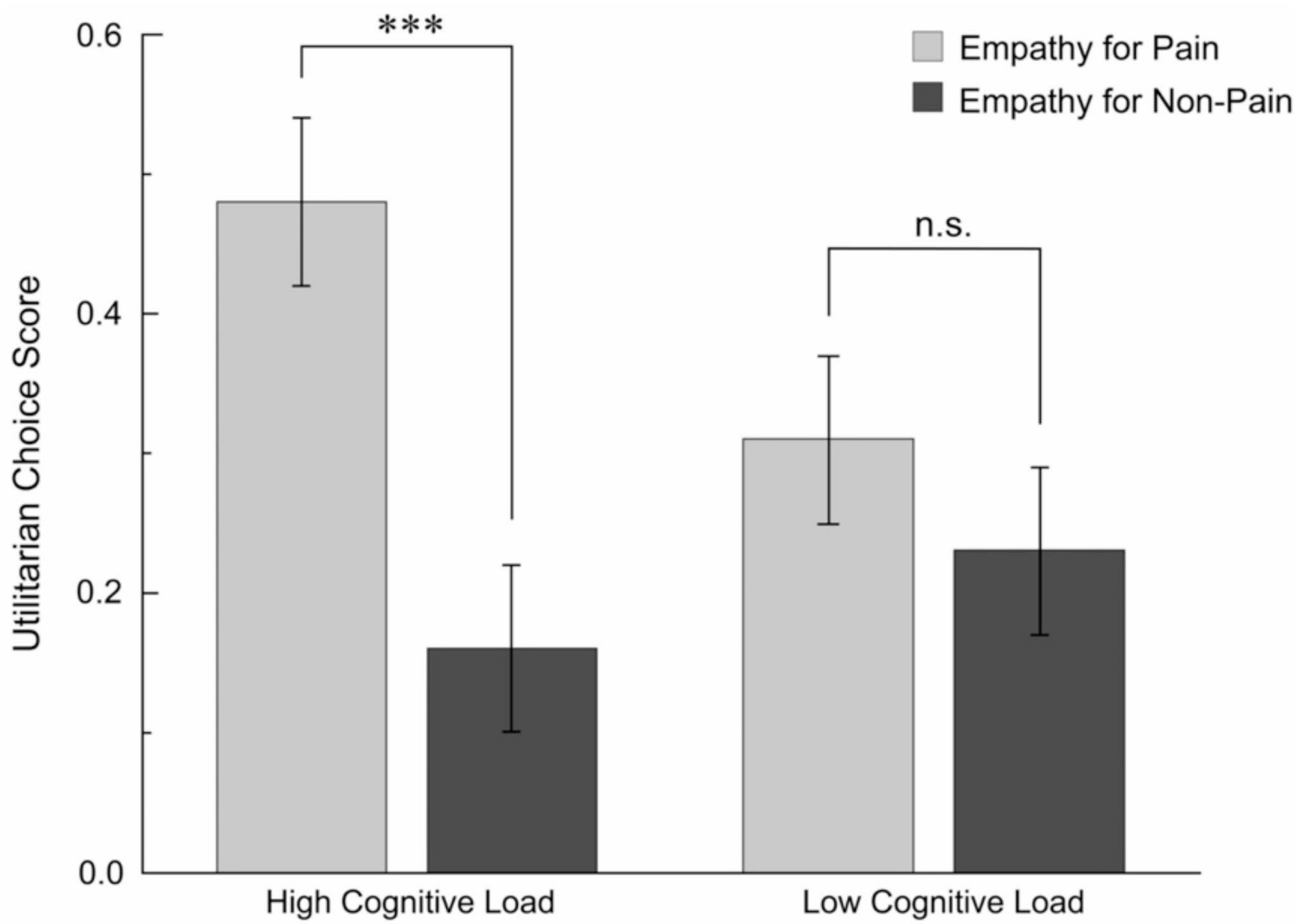

Fig. 4 Utilitarian choice scores of individuals under different cognitive loads and levels of empathy for pain ($M \pm SE$). *Note*: Error bars represent standard error, $^{***}p < 0.001$, n.s. indicates no significant difference

Table 2 Descriptive statistics of moral decision-making scores under different moral dilemmas, cognitive load and empathy for pain ($M \pm SD$)

Moral dilemmas	Cognitive load	Empathy for pain	*M*	*SD*
Impersonal Dilemma	High Load	Empathy for Pain	0.58	0.34
		Empathy for Non-Pain	0.20	0.30
	Low Load	Empathy for Pain	0.45	0.34
		Empathy for Non-Pain	0.27	0.27
Personal Dilemma	High Load	Empathy for Pain	0.38	0.28
		Empathy for Non-Pain	0.12	0.21
	Low Load	Empathy for Pain	0.17	0.20
		Empathy for Non-Pain	0.20	0.30

General discussion

Moral decision-making tendencies under different presentation modes, empathy for pain, and moral dilemmas

The utilitarian tendency in moral decision-making reflects the pursuit of greater societal benefit (Shao et al., 2008). Experiment 1 showed that presentation modes and moral dilemma types influence decision-making tendencies. Specifically, individuals made more utilitarian decisions in impersonal dilemmas under VR conditions, while they made fewer utilitarian decisions in personal dilemmas. This result supports H2 of the present study and is consistent with previous research (Patil et al., 2014; Francis et al., 2016). Studies suggest that switching the track in the trolley problem is generally viewed as acceptable (Hauser et al., 2007). This is due to the limitations of text-based presentations, which rely solely on questionnaire responses. The conclusions may not accurately reflect individuals' real-world behavior, and it remains uncertain whether their moral choices in real-life situations would align with these responses (Feldmanhall et al., 2012). In a VR environment, individuals perceive decision outcomes more intuitively. This immersive experience heightens the perceived realism of the dilemma, influencing the judgment process. Embodied cognition theory explains this phenomenon, positing that cognition depends not only on neural computations but also on body-environment interactions (Ye, 2023), there is a strong interaction between the body and moral situations. This strengthens the ecological validity of VR-based experiments, making the results more interpretable and generalizable. Additionally, the VR environment plays a critical role in activating empathy (Modena & Pinotti, 2020), a key factor in moral decision-making. Individuals can better understand that the survival of the five people in the VR scenario benefits society as a whole. Consequently, they are more likely to prioritize the greater good in decision-making, in line with the core principle of utilitarianism—maximizing overall benefit.

In addition, research shown that moral dilemmas activate distinct decision-making systems (Greene et al., 2001; Hauser et al., 2007). According to the dual-process theory, moral judgment involves two distinct systems: a slow, conscious, and controlled cognitive reasoning system, and a fast, unconscious, and automatic emotional-intuitive system. Both systems operate simultaneously when individuals make moral judgments. When emotions dominate, individuals tend to make deontological judgments, while cognitive dominance leads to utilitarian judgments (Cushman & Greene, 2012). Neuroimaging studies have shown that the dorsolateral prefrontal cortex (DLPFC) serves as the primary neural basis for utilitarian judgment, reflecting a cognitively driven process. In contrast, the ventromedial prefrontal cortex (VMPFC) is the primary neural basis for deontological judgment, representing an emotionally driven process (Greene et al., 2001). The dual-process theory suggests that automatic emotional responses to harm evoke deontological judgments, while cost-benefit reasoning elicits utilitarian judgments. This theory suggests that people feel aversion when directly harming others. In highly conflicting personal dilemmas, such as pushing one person to save many others, strong aversive emotions typically lead to deontological judgments (Greene, 2007). Conversely, weaker emotional responses lead to behavior driven by utilitarian reasoning (Patil & Silani, 2014). The VR environment allows individuals to experience the consequences of harm in dilemmas, making it easier for them to weigh costs and benefits and make utilitarian choices.

Both Experiment 1 and Experiment 2 showed significant differences based on the type of moral dilemmas, in line with previous studies (Moore et al., 2011). Experiment 2 further showed that, in impersonal dilemmas, individuals experiencing empathy for pain were more likely to make utilitarian choices. This may be because empathy combines cognitive and emotional capacities, requiring both an understanding of others' thoughts and feelings, and resonance with their emotions (Farrow & Woodruff, 2007). According to the dual-process theory, moral decision-making involves the simultaneous activation of both emotional and cognitive systems. Impersonal dilemmas rely primarily on cognitive processing, whereas personal dilemmas are predominantly influenced by emotional responses. This phenomenon can be explained through the relationship between emotional experience and decision-making distance. Variations in event construal levels reflect differences in individual responses and decisions (Alper, 2020), suggesting that psychological proximity to a cognitive target influences decision-making (VanHorn, 2020). For example, reduced psychological distance to a cognitive target enhances emotional experiences. In impersonal dilemmas, where psychological distance is greater than in personal dilemmas, individuals are more likely to empathize with others' pain and rationally weigh costs and benefits to make utilitarian decisions prioritizing greater societal benefit. However, in the personal dilemma of the footbridge scenario, despite high empathy for pain, individuals cannot accept directly pushing someone to their death to save others, resulting in strong moral stress. In contrast, in the trolley dilemma, participants can indirectly switch the track to sacrifice one person to save others, reducing direct involvement and moral responsibility. This phenomenon suggests that impersonal dilemmas require more deliberate reasoning, while personal dilemmas rely more on intuition. These findings support previous research (Greene, 2007).

The role of empathy for pain under high cognitive load

Experiment 1 showed that individuals under high cognitive load made fewer utilitarian choices, supporting H1a. This finding aligns with previous research (Trémolière & Bonnefon, 2014). Cognitive resource theory posits that individuals deplete finite cognitive resources when engaged in goal-directed tasks. When a task consumes a significant portion of these resources, cognitive capacity for other tasks diminishes (Giesbrecht et al., 2014; Yuan & Liu, 2021). Under limited cognitive resources, individuals tend to rely more on the emotional system for decision-making, leading to fewer utilitarian choices. In contrast, under low cognitive load, individuals allocate more attention to moral judgment, resulting in more utilitarian choices.

In Experiment 2, conducted in a virtual reality environment, individuals under high cognitive load exhibited lower mental effort and higher relaxation degree at the empathy for pain level. This phenomenon indicated that empathy affects both moral decision-making and physiological reaction under high cognitive load. Research indicates that empathy for pain automatically triggers emotional processing, there is no need for individuals to actively mobilize cognitive resources. When individuals observe or imagine others in pain, their emotional system responds automatically, requiring no additional cognitive effort (Preston & De Waal, 2002). In the early stages of processing, the activation and sharing of others' emotional states exhibit characteristics of automatic processing (Ibanez et al., 2011). This aligns closely with the emotional system outlined in the dual-process theory. When individuals engage in tasks involving empathy for pain, their psychological and physiological responses follow a distinct pattern (Singer et al., 2004). Typically, when individuals are involved in high-intensity work or deep thinking, they experience increased tension and more frequent mental effort. However, when empathy for pain acts as a distraction in high cognitive load situations, it may alleviate the tension and reduce the brain energy consumption associated with the cognitive task. Consequently, this may enhance relaxation degree and reduce empathy for pain under high cognitive load. Additionally, in high-pressure or resource-limited situations, individuals are more inclined to adopt avoidance strategies (Gelfand et al., 2011). This stimulus of feeling pain may lead to emotional numbness, which reduces mental effort and increases relaxation degree.

In addition, the study further showed that inducing empathy for pain mitigates the effect of cognitive load on moral decision-making tendencies. At high cognitive load, individuals experiencing empathy for pain were more likely to make utilitarian choices, this result supports H1b. Within the framework of the dual-process theory, this mechanism explains how cognitive load and empathy for pain interact in moral decision-making. Under high cognitive load, individuals have limited cognitive resources, resulting in more reliance on rapid emotional systems to make decisions. Induced empathy for pain activates the emotional system, increasing sensitivity to others' suffering and strengthening utilitarian tendencies. This phenomenon showed that empathy for pain moderates the effect of cognitive load on moral decision-making and may also direct individuals toward maximizing societal benefits via the emotional system (Gu et al., 2024). For example, individuals experiencing empathy for pain may perceive sacrificing five lives as causing greater suffering than sacrificing one, leading them to choose to save five at the expense of one, thereby reinforcing the motivation to maximize overall welfare.

Empathy for pain influences both emotional experience and moral cognitive frameworks. Research indicates that cognitive load is influenced by the environment (Luo et al., 2024), and interfering stimuli diminish its impact. As a distraction, empathy for pain mitigates the influence of cognitive load on moral decision-making and enhances emotional resonance. In high-load situations, it promotes a more resource-efficient cognitive strategy, reducing cognitive task investment. This finding offers a novel perspective on the interplay between empathy and cognitive load. It suggests that in certain contexts, empathy optimizes cognitive resource allocation, allowing individuals to efficiently identify key aspects of moral decision-making and favor utilitarian choices.

Limitations and prospects

While valuable, this study has several limitations. First, gender differences can affect moral decision-making (Brannon et al., 2019). The gender imbalance among participants may have introduced bias, limiting the generalizability of the findings. Future studies should explore gender's impact on moral decision-making in greater depth. Second, research on empathy for pain has mainly examined its cognitive neural mechanisms using methods like functional magnetic resonance imaging (fMRI) and electroencephalography (EEG) (Singer et al., 2004). Despite progress in understanding the neural basis of empathy for pain, its role in moral decision-making remains underexplored. Experiment 2 included limited brainwave data, preventing a comprehensive understanding of empathy for pain's neural mechanisms in moral decision-making. Future studies should combine psychological and neuroscientific methods for a more comprehensive investigation. Finally, treating empathy for pain as a factor that reduces cognitive load may have impacted the accuracy of cognitive load assessment. Future research should examine how empathy for pain affects cognitive processes, including attention allocation, working memory, and decision-making, and its relationship with cognitive load variations. Incorporating moral intensity measures and ensuring pain-related stimuli align with moral dilemmas may improve the validity of studies on moral factors in empathy for pain and cognitive load.

Conclusion

The following conclusions are drawn from this study: (1) In the VR presentation modes, individuals tend to make utilitarian choices, whether in impersonal dilemma or personal dilemma; individuals experiencing high cognitive load tend to make fewer utilitarian choices. (2) At the level of empathy for pain, high-load individuals have lower mental effort and higher relaxation degree. (3) Under the impersonal dilemma and high-load of VR, individuals at the level of empathy for pain are more inclined to utilitarian choices.

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Data availability We report how we determined our sample size, all data exclusions (if any), all manipulations, and all measures in the study, and we follow JARS (Kazak, 2018). All data have been made publicly available at the OSF and can be accessed at https://osf.io/j3znq/?view_only=acbb84b3cc054a688db1482e9da403c8. Data were analyzed using SPSS (Version 25). This study's design and its analysis were not preregistered.

Declarations

This study has been approved by the first author's institution for ethical review, comply with the provisions of the World Medical Association Code of Ethics (Declaration of Helsinki) concerning experiments involving humans. Due to different institutional policies, there is no approval number.

Consent for publication All authors of this study agreed to sign an informed statement.

Consent to participate Participants volunteered to participate in the experiment and signed a paper version of the experimental informed consent. Prior to the start of the experiment, the procedure, purpose and duration of the experiment are informed, and the experiment can be withdrawn at any time, without any potential risk, and the privacy of human participants is always respected.

Conflict of interest The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

References

Alper, S. (2020). Explaining the complex effect of construal level on moral and political attitudes. *Current Directions in Psychological Science*, *29*(2), 115–120. https://doi.org/10.1177/0963721419896362

Awad, E., Dsouza, S., Shariff, A., Rahwan, I., & Bonnefon, J. F. (2020). Universals and variations in moral decisions made in 42 countries by 70,000 participants. *Proceedings of the National Academy of Sciences*, *117*(5), 2332–2337. https://doi.org/10.1073/pnas.1911517117

Barrouillet, P., Bernardin, S., Portrat, S., Vergauwe, E., & Camos, V. (2007). Time and cognitive load in working memory. *Journal of Experimental Psychology: Learning Memory and Cognition*, *33*(3), 570–585. https://doi.org/10.1037/0278-7393.33.3.570

Bartels, D. M. (2008). Principled moral sentiment and the flexibility of moral judgment and decision making. *Cognition*, *108*(2), 381–417. https://doi.org/10.1016/j.cognition.2008.03.001

Batson, C. D. (2014). *The altruism question: Toward a social-psychological answer*. Psychology Press. https://doi.org/10.4324/9781315808048

Brannon, S. M., Carr, S., Jin, E. S., Josephs, R. A., & Gawronski, B. (2019). Exogenous testosterone increases sensitivity to moral norms in moral dilemma judgements. *Nature Human Behaviour*, *3*, 856–866. https://doi.org/10.1038/s41562-019-0641-3

Chen, X., Wu, Z., Zhan, B., Ding, D., & Zhang, X. (2023). Effects of alexithymia on moral decision-making in sacrificial dilemmas: High alexithymia is associated with weaker sensitivity to moral norms. *Psychology Research and Behavior Management*, *16*, 2315–2325. https://doi.org/10.2147/prbm.s407744

Cheng, Z. B., & Huang, Y. (2012). Neural mechanisms underlying empathy for pain. *Journal of Psychological Science*, *35*(2), 436–440. https://doi.org/10.16719/j.cnki.1671-6981.2012.02.001

Cheng, J. P., Luo, Y. J., & Cui, F. (2017). Empathy for pain influenced by cognitive load: Evidence from an ERP study. *Acta Psychologica Sinica*, *49*(5), 622–630. https://doi.org/10.3724/SP.J.1041.2017.00622

Christensen, J. F., & Gomila, A. (2012). Moral dilemmas in cognitive neuroscience of moral decision-making: A principled review. *Neuroscience & Biobehavioral Reviews*, *36*(4), 1249–1264. https://doi.org/10.1016/j.neubiorev.2012.02.008

Conway, P., & Gawronski, B. (2013). Deontological and utilitarian inclinations in moral decision making: A process dissociation approach. *Journal of Personality and Social Psychology*, *104*(2), 216–235. https://doi.org/10.1037/a0031021

Cushman, F., & Greene, J. D. (2012). Finding faults: How moral dilemmas illuminate cognitive structure. *Social Neuroscience*, *7*(3), 269–279. https://doi.org/10.1080/17470919.2011.614000

Davis, M. H. (1983). Measuring individual differences in empathy: Evidence for a multidimensional approach. *Journal of Personality and Social Psychology*, *44*(1), 113–126. https://doi.org/10.1037/0022-3514.44.1.113

Dehais, F., Dupres, A., Di Flumeri, G., Verdiere, K., Borghini, G., Babiloni, F., & Roy, R. (2018). Monitoring pilot's cognitive fatigue with engagement features in simulated and actual flight conditions using an hybrid fNIRS-EEG passive BCI. In *2018 IEEE international conference on systems, man, and cybernetics (SMC)* (pp. 544–549). IEEE. https://doi.org/10.1109/smc.2018.00102

Du, R., & Chen, J. (2024). Empathy and social behaviors: Influences of pain and fear perceptions on interpersonal interactions. *Journal of Air Force Medical University*, *45*(12), 1347–1352. https://doi.org/10.13276/j.issn.2097-1656.2024.12.002

Farrow, T. F., & Woodruff, P. W. (Eds.). (2007). *Empathy in mental illness*. Cambridge University Press. https://doi.org/10.1017/cbo9780511543753

Faul, F., Erdfelder, E., Lang, A. G., & Buchner, A. (2007). G* power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods*, *39*(2), 175–191. https://doi.org/10.3758/bf03193146

Feldmanhall, O., Mobbs, D., & Evans, D. (2012). What we say and what we do: The relationship between real and hypothetical moral choices. *Cognition*, *123*(3), 434–441. https://doi.org/10.1016/j.cognition.2012.02.001

Francis, K. B., Howard, C., Howard, I. S., Gummerum, M., Ganis, G., Anderson, G., & Terbeck, S. (2016). Virtual morality: Transitioning from moral judgment to moral action? *PloS One*, *11*(10). https://doi.org/10.1371/journal.pone.0164374. Article e0164374.

Gelfand, M. J., Raver, J. L., Nishii, L., Leslie, L. M., Lun, J., Lim, B. C., & Yamaguchi, S. (2011). Differences between tight and loose cultures: A 33-nation study. *Science*, *332*(6033), 1100–1104. https://doi.org/10.1126/science.1197754

Giesbrecht, B., Sy, J., Bundesen, C., & Kyllingsbæk, S. (2014). A new perspective on the perceptual selectivity of attention under load. *Annals of the New York Academy of Sciences*, *1316*(1), 71–86. https://doi.org/10.1111/nyas.12404

Gilbert, D. T., Pelham, B. W., & Krull, D. S. (1988). On cognitive busyness: When person perceivers Meet persons perceived. *Journal of Personality and Social Psychology*, *54*(5), 733–740. https://doi.org/10.1037/0022-3514.54.5.733

Girardi, D., Lanubile, F., & Novielli, N. (2017). Emotion detection using noninvasive low cost sensors. In *2017 seventh international conference on affective computing and intelligent interaction (ACII)* (pp. 125–130). IEEE. https://doi.org/10.1109/acii.2017.8273589

Greene, J. D. (2007). Why are VMPFC patients more utilitarian? A dual-process theory of moral judgment explains. *Trends in*

Cognitive Sciences, *11*(8), 322–323. https://doi.org/10.1016/j.tics.2007.06.004
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. https://doi.org/10.1126/science.1062872
Greene, J. D., Morelli, S. A., Lowenberg, K., Nystrom, L. E., & Cohen, J. D. (2008). Cognitive load selectively interferes with utilitarian moral judgment. *Cognition*, *107*(3), 1144–1154. https://doi.org/10.1016/j.cognition.2007.11.004
Greitemeyer, T. (2013). Playing video games cooperatively increases empathic concern. *Social Psychology*, *44*(6), 408–413. https://doi.org/10.1027/1864-9335/a000154
Gu, R. L., He, Y., & Cui, F. (2024). Reconsidering the relationship between empathy and prosocial behavior. *Chinese Science Bulletin*, *59*(5), 1–9. https://doi.org/10.1360/TB-2024-0025
Guan, X., Zhang, F., Zhou, N., & Yin, J. (2017). The foreign Language effect in decision making and moral judgment: Retrospect and prospect. *Chinese Journal of Applied Psychology*, *23*(1), 80–91. https://doi.org/10.3969/j.issn.1006-6020.2017.01.009
Haidt, J. (2001). The emotional dog and its rational Tail: A social intuitionist approach to moral judgment. *Psychological Review*, *108*(4), 814–834. https://doi.org/10.1037/0033-295x.108.4.814
Hatfield, E., Cacioppo, J. T., & Rapson, R. L. (1993). Emotional contagion. *Current Directions in Psychological Science*, *2*(3), 96–100. https://doi.org/10.1111/1467-8721.ep10770953
Hauser, M., Cushman, F., Young, L., Kang-Xing Jin, R., & Mikhail, J. (2007). A dissociation between moral judgments and justifications. *Mind & Language*, *22*(1), 1–21. https://doi.org/10.1111/j.1468-0017.2006.00297.x
He, L., Li, H., Xue, T., Sun, D., Zhu, S., & Ding, G. (2018). Am I in the theater? Usability study of live performance based virtual reality. In *Proceedings of the 24th ACM Symposium on Virtual Reality Software and Technology*(pp. 1–11). https://doi.org/10.1145/3281505.3281508
Hiraoka, D., & Nomura, M. (2016). The influence of cognitive load on empathy and intention in response to infant crying. *Scientific Reports*, *6*(1), 28247. https://doi.org/10.1038/srep28247
Holmes, A., Mogg, K., de Fockert, J., Nielsen, M. K., & Bradley, B. P. (2014). Electrophysiological evidence for greater attention to threat when cognitive control resources are depleted. *Cognitive Affective & Behavioral Neuroscience*, *14*, 827–835. https://doi.org/10.3758/s13415-013-0212-4
Ibáñez, A., Hurtado, E., Lobos, A., Escobar, J., Trujillo, N., Baez, S., & Decety, J. (2011). Subliminal presentation of other faces (but not own face) primes behavioral and evoked cortical processing of empathy for pain. *Brain Research*, *1398*, 72–85. https://doi.org/10.1016/j.brainres.2011.05.014
Jackson, P. L., Brunet, E., Meltzoff, A. N., & Decety, J. (2006). Empathy examined through the neural mechanisms involved in imagining how I feel versus how you feel pain. *Neuropsychologia*, *44*(5), 752–761. https://doi.org/10.1016/j.neuropsychologia.2005.07.015
Jones, T. M. (1991). Ethical decision making by individuals in organizations: An issue-contingent model. *Academy of Management Review*, *16*(2), 366–395. https://doi.org/10.5465/amr.1991.4278958
Kazak, A. E. (2018). Editorial: Journal Article reporting standards. *American Psychologist*, *73*(1), 1–2. https://doi.org/10.1037/amp0000263
Klenk, M. (2022). The influence of situational factors in sacrificial dilemmas on utilitarian moral judgments: A systematic review and meta-analysis. *Rev Philos Psychol*, *13*, 593–625. https://doi.org/10.1007/s13164-021-00547-4
Lin, L. F., & Gao, H. (2020). Foreign Language effect and framing effect in moral judgment. *Psychology: Techniques and Applications*, *8*(11), 671–678. https://doi.org/10.16842/j.cnki.issn2095-5588.2020.11.004
Liu, C. J., & Liao, J. Q. (2021). The development of empirical paradigms and their theoretical values in moral dilemma research. *Advances in Psychological Science*, *29*(8), 1508–1520. https://doi.org/10.3724/SP.J.1042.2021.01508
Luo, L., Zhang, M. H., Zhang, G. H., & Dong, K. L. (2024). Research on the development of Industry-Education integration digital textbook in vocational Education—Mechanism analysis based on cognitive load. *Chinese Vocational and Technical Education*, *32*, 87–95.
Macrotellect (2023). Brainlink Pro. https://o.macrotellect.com/default.html
Martinez, R. M., Chou, S. H., Fan, Y. T., Chen, Y. C., Goh, K. K., & Chen, C. (2024). Negative emotionality downregulation affects moral choice but not moral judgement of harm: A Pharmacological study. *Scientific Reports*, *14*(1), 1200. https://doi.org/10.1038/s41598-024-51345-8
Meng, J., Hu, L., Shen, L., Yang, Z., Chen, H., Huang, X., & Jackson, T. (2012). Emotional primes modulate the responses to others' pain: An ERP study. *Experimental Brain Research*, *220*, 277–286. https://doi.org/10.1007/s00221-012-3136-2
Meng, J., Jackson, T., Chen, H., Hu, L., Yang, Z., Su, Y., & Huang, X. (2013). Pain perception in the self And observation of others: An ERP investigation. *Neuroimage*, *72*, 164–173. https://doi.org/10.1016/j.neuroimage.2013.01.024
Meng, J., Li, Y., Luo, L., Li, L., Jiang, J., Liu, X., & Shen, L. (2024). The empathy for pain stimuli system (EPSS): Development and preliminary validation. *Behavior Research Methods*, *56*, 784–803. https://doi.org/10.3758/s13428-023-02087-4
Modena, E., & Pinotti, A. (2020). Humanitarian VR as 360◦ autopsy: Empathy and sympathy in immersive storytelling. In C. Haug, & V. Kaufmann (Eds.), *Kodex: Jahrbuch der internationalen buchwissenschaftlichen gesellschaft* (pp. 145–162). Harrassowitz.
Moore, A. B., Lee, N. L., Clark, B. A., & Conway, A. R. (2011). In defense of the personal/impersonal distinction in moral psychology research: Cross-cultural validation of the dual process model of moral judgment. *Judgment and Decision Making*, *6*(3), 186–195. https://doi.org/10.1017/s193029750000139x
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. https://doi.org/10.1037/a0025561
Niso, G., Romero, E., Moreau, J. T., Araujo, A., & Krol, L. R. (2023). Wireless EEG: A survey of systems and studies. *Neuroimage*, *269*, 119774. https://doi.org/10.1016/j.neuroimage.2022.119774
Patil, I., & Silani, G. (2014). Reduced empathic concern leads to utilitarian moral judgments in trait alexithymia. *Frontiers in Psychology*, *5*, 501. https://doi.org/10.3389/fpsyg.2014.00501
Patil, I., Cogoni, C., Zangrando, N., Chittaro, L., & Silani, G. (2014). Affective basis of judgment-behavior discrepancy in virtual experiences of moral dilemmas. *Social Neuroscience*, *9*(1), 94–107. https://doi.org/10.1080/17470919.2013.870091
Patil, I., Larsen, E. M., Kichic, R., & Gleichgerrcht, E. (2021). Moral cognition about harm in anxiety disorders: The importance of experienced emotion. *Psychological Reports*, *124*(6), 2501–2523. https://doi.org/10.1177/0033294120964134
Pletti, C., Sarlo, M., Palomba, D., Rumiati, R., & Lotto, L. (2015). Evaluation of the legal consequences of action affects neural activity and emotional experience during the resolution of moral dilemmas. *Brain and Cognition*, *94*, 24–31. https://doi.org/10.1016/j.bandc.2015.01.004
Preston, S. D., & De Waal, F. B. (2002). Empathy: Its ultimate and proximate bases. *Behavioral and Brain Sciences*, *25*(1), 1–20. https://doi.org/10.1017/s0140525x02000018

Ren, Q. Y., Yang, Y., Wo, Y., Lu, X. J., & Hu, L. (2022). Different priming effects of empathy on neural processing associated with firsthand pain and nonpain perception. *Annals of the New York Academy of Sciences*, *1509*(1), 184–202. https://doi.org/10.1111/nyas.14723

Rilling, J. K., & Sanfey, A. G. (2011). The neuroscience of social decision-making. *Annual Review of Psychology*, *62*, 23–48. https://doi.org/10.1146/annurev.psych.121208.131647

Rizzolatti, G., & Craighero, L. (2004). The mirror-neuron system. *Annual Review of Neuroscience*, *27*, 169–192. https://doi.org/10.1146/annurev.neuro.27.070203.144230

Royzman, E. B., Landy, J. F., & Leeman, R. F. (2015). Are thoughtful people more utilitarian? CRT as a unique predictor of moral minimalism in the dilemmatic context. *Cognitive Science*, *39*(2), 325–352. https://doi.org/10.1111/cogs.12136

Schwartz, F., Djeriouat, H., & Trémolière, B. (2021). The association between personality traits and third-party moral judgment: A preregistered study. *Acta Psychologica*, *219*, 103392. https://doi.org/10.1016/j.actpsy.2021.103392

Schwartz, F., Djeriouat, H., & Trémolière, B. (2022). Agents' moral character shapes People's moral evaluations of accidental harm transgressions. *Journal of Experimental Social Psychology*, *102*, 104378. https://doi.org/10.1016/j.jesp.2022.104378

Shao, R., Aquino, K., & Freeman, D. (2008). Beyond moral reasoning: A review of moral identity research and its implications for business ethics. *Business Ethics Quarterly*, *18*(4), 513–540. https://doi.org/10.5840/beq200818436

Singer, T., Seymour, B., O'doherty, J., Kaube, H., Dolan, R. J., & Frith, C. D. (2004). Empathy for pain involves the affective but not sensory components of pain. *Science*, *303*(5661), 1157–1162. https://doi.org/10.1126/science.1093535

Thomas, B. C., Croft, K. E., & Tranel, D. (2011). Harming kin to save strangers: Further evidence for abnormally utilitarian moral judgments after ventromedial prefrontal damage. *Journal of Cognitive Neuroscience*, *23*(9), 2186–2196. https://doi.org/10.1162/jocn.2010.21591

Trémolière, B., & Bonnefon, J. F. (2014). Efficient kill–save ratios ease up the cognitive demands on counterintuitive moral utilitarianism. *Personality and Social Psychology Bulletin*, *40*(7), 923–930. https://doi.org/10.1177/0146167214530436

Tsai, M. H., Hsia, C. Y., Wu, S. K., & Chen, T. L. (2020). An individual specific electroencephalography signal pattern verification model based on machine learning and convolutional neural network. *J Adv Comput Netw*, *8*(1), 1–9. https://doi.org/10.18178/jacn.2020.8.1.272

VanHorn, D., R (2020). Adaptive psychological distance: A survival perceived Temporal distance effect. *Evolutionary Psychology*, *18*(3), 1–7. https://doi.org/10.1177/1474704920948785

Vavra, P., Galván, E. P., & Sanfey, A. G. (2024). Moral decision-making in context: Behavioral and neural processes underlying allocations based on need, merit, and equality. *Cortex; A Journal Devoted To the Study of the Nervous System and Behavior*, *177*, 53–67. https://doi.org/10.1016/j.cortex.2024.03.015

Wu, D., Ouyang, J., Dai, N., Wu, M., Tan, H., Deng, H., & Jin, Z. (2022). DeepBrain: Enabling fine-grained brain-robot interaction through human-centered learning of coarse EEG signals from low-cost devices. *Proceedings of the ACM on Interactive Mobile Wearable and Ubiquitous Technologies*, *6*(3), 1–27. https://doi.org/10.1145/3550334

Yang, Q., & Shen, X. Y. (2024). Utilitarianism in moral dilemma: The disguise of alexithymia. *Chinese Journal of Health Psychology*, *22*(11), 1660–1664. https://doi.org/10.13342/j.cnki.cjhp.2024.11.011

Ye, H. S. (2023). Embodied Mind and embodied education. *Educational Research*, *44*(3), 32–41.

Yuan, X. J., & Liu, C. (2021). Moral intuition is moral but not objective. *Advances in Psychological Science*, *29*(11), 2083–2090. https://doi.org/10.3724/SP.J.1042.2021.02083

Zhan, Y. L., Xiao, X., Tan, Q. B., Li, J., & Zhong, Y. P. (2022). Influence of reputational concern and social distance on moral decision-making under the harmful dilemma: Evidence from behavioral and erps study. *Acta Psychologica Sinica*, *54*(6), 613–627. https://doi.org/10.3724/SP.J.1041.2022.00613