



Title	Interoceptive Brain Processing Influences Moral Decision Making
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## 論文内容の要旨

## Synopsis of Thesis

氏名 Name	CUI Shengbin
論文題名 Title	Interoceptive Brain Processing Influences Moral Decision Making (脳内の内受容感覚処理が道徳意思決定に与える影響)
<b>Objective</b>	
<p>This study investigated whether the brain's moment-to-moment monitoring of one's own bodily state – in this case, the brain's responses to heartbeats – plays a functional role in moral reasoning. Moral neuroscience research has long distinguished deontological choices, which forbid harmful actions on principle, from utilitarian choices, which permit harm if it maximizes overall welfare. This study hypothesized that interoceptive processing might bias moral decision and predicted that the heartbeat-evoked potential (HEP), an EEG index of cardiac interoceptive processing, would differ according to the decision adopted, irrespective of whether the moral dilemma required direct harm against others (a personal dilemma) or indirect harm against others (an impersonal dilemma).</p>	
<b>Methods/Results</b>	
<p>To test this, twenty-seven Japanese university students (15 female; mean age = <math>22.11 \pm 2.1</math> years) completed thirty-six scenarios, evenly split between personal dilemmas (e.g., pushing a person off a footbridge to stop a runaway trolley) and impersonal dilemmas (e.g., pulling a switch to divert the trolley). Each trial comprised a Scenario phase, during which participants read the text, and a Decision phase, during which they selected one of four graded response options ranging from extreme utilitarian to extreme deontological decisions. While participants performed the task, 64-channel EEG and three-lead ECG were recorded at 500 Hz. R-peaks detected in the ECG served to time-lock EEG epochs, allowing to computations of HEP waveforms between -200 and 600 s relative to each heartbeat. A cluster-based permutation approach evaluated amplitude differences while controlling for multiple comparisons. Independent behavioral measures, including reading times, choice distributions, and response latencies, were analyzed alongside cardiac indices to rule out confounds.</p>	
<p>Behaviorally, participants were more inclined toward utilitarian decisions in impersonal dilemmas (mean = 73%) than in personal dilemmas (mean = 59%), replicating a well-established effect. Reading times were longer for impersonal dilemmas, whereas decision times were longest when participants eventually chose the deontological option, reflecting heightened cognitive conflict. These task differences, however, did not predict variations in HEP amplitude once they were entered as covariates, indicating that the interoceptive findings could not be reduced to general task difficulty or arousal.</p>	
<p>Electrophysiologically, utilitarian decisions were accompanied by more negative HEP deflections, a pattern observed in two distinct latency ranges: 110-170ms over centro-parietal electrodes during the Scenario phase and 314-404ms over right fronto-temporal electrodes during the Decision phase. By contrast, the personal-versus-impersonal manipulation did not modulate HEPs at any latency, suggesting that direct bodily harm per se is not what drives the interoceptive engagement. Surrogate heartbeat analyses confirmed that the effects arose from genuine brain-heart coupling rather than stimulus-locked artifacts, and individual differences in alexithymia (a trait index of interoceptive awareness) did not account for the effect sizes.</p>	
<b>Conclusion</b>	
<p>The findings support somatic-marker theories of moral cognition by showing that transient fluctuations in interoceptive brain activity bias ethical judgments. In this dataset, a more negative HEP preceded and accompanied utilitarian choices, regardless of whether the dilemma required direct or indirect harm. Thus, the neural representation of cardiac signals influences moral decision-making even before an explicit response is made, underscoring the functional relevance of visceral information in complex social cognition. Beyond basic science, the work opens avenues for modulating ethical behavior through interventions – such as biofeedback or pharmacological agents – that target interoceptive processing.</p>	

## 論文審査の結果の要旨及び担当者

(申請者氏名) CUI Shengbin			
論文審査担当者	(職)	氏名	
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<b>論文審査の結果の要旨</b>			
人間は、複雑な状況下で迅速かつ適切な意思決定を日々求められている。こうした意思決定において、予測的な内受容感覚がどのように脳に表現され、意思決定に関与しているかは、未だに解明されていない。そこで、Cui氏は、心拍に同期して生じる脳活動 (Heartbeat-Evoked Potential: HEP) に注目し、社会的意思決定との関係を検証する研究を実施した。具体的には、道徳のジレンマとして知られるトロッコ問題において、行動選択（大勢の命を救うために、関係ない人の命を犠牲にするか否か）が直前の右前頭側頭部のHEP振幅によってバイアスされることを明らかにした。この成果は『Human Brain Mapping』誌に掲載された (Cui & Nakano, 2024)。以上の研究は、身体内受容感覚の脳活動が社会的意思決定に関与することを世界で初めて実証した点で意義深い。社会や政治を含む複雑な意思決定の神経基盤の解明は、学術的にも社会的にも大きな意義を持つことから、Cui氏の研究は学位の授与に値すると考えられる。			