MORAL DECISION-MAKING UNDER UNCERTAINTY: THE ROLE OF BRAIN CENTRES, COGNITIVE STYLES, AND ATTRIBUTIONAL STYLES

МОРАЛЬНІ РІШЕННЯ В УМОВАХ НЕВИЗНАЧЕНОСТІ: РОЛЬ МОЗКОВИХ ЦЕНТРІВ, КОГНІТИВНИХ ТА АТРИБУЦІЙНИХ СТИЛІВ

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This study explores the intricate and multifaceted process of moral decision-making under conditions of uncertainty, integrating comprehensive findings from cognitive neuroscience, psychology, and moral philosophy. The research meticulously examines the critical roles of the ventromedial prefrontal cortex (vmPFC), anterior cingulate cortex (ACC), and amygdala, highlighting their involvement in processing cognitive and emotional information that significantly influences moral judgments. A thorough investigation into how different cognitive styles, such as analytic versus holistic thinking and intuitive versus deliberative processing, shape individual approaches to complex moral dilemmas is conducted. The study further delves into attributional styles, with a focus on how internal versus external and stable versus unstable attributions affect perceptions of responsibility, ethical decision-making, and moral accountability. The challenges posed by moral uncertainty are extensively addressed, drawing on diverse philosophical frameworks that guide decision-making processes when moral principles are either unclear or in direct conflict. By integrating these multidisciplinary insights, the study provides a nuanced understanding of how these various cognitive, emotional, and social factors interact to influence moral choices in contexts that are often ambiguous and fraught with uncertainty. The findings underscore the complexity of moral cognition, suggesting that effective moral decision-making requires a balanced consideration of both cognitive strategies and emotional responses, particularly in situations where outcomes are uncertain and the ethical path is not well-defined. Moreover, the implications of these findings extend to practical applications in fields such as ethics, decision-making, psychology, and public policy, where understanding the interplay between cognitive and emotional factors can enhance the quality of decisions made under morally challenging conditions.
Key words: *moral decision-making, uncertainty, ventromedial prefrontal cortex, anterior cingulate cortex, amygdala, cognitive styles, attributional styles, moral uncertainty.*

У даному дослідженні ретельно розглядається складний та багатогранний процес прийняття моральних рішень в умовах невизначеності, з інтеграцією широких результатів когнітивної нейронауки, психології та моральної філософії. Дослідження детально вивчає критичну роль вентромедіальної префронтальної кори (vmPFC), передньої поясної кори (ACC) та мигдалеподібного тіла, підкреслюючи їх важливість у процесах обробки когнітивної та емоційної інформації, що суттєво впливає на моральні судження. Ретельно досліджується, як різні когнітивні стилі, такі як аналітичне та холістичне мислення, інтуїтивний та свідомий процеси, формують підходи до складних моральних дилем. Дослідження також глибоко аналізує атрибуційні стилі, зокрема те, як внутрішні та зовнішні, стабільні та нестабільні атрибуції впливають на сприйняття відповідальності, прийняття етичних рішень та моральну відповідальність. Особливу увагу приділено викликам, пов'язаним з моральною невизначеністю, з використанням різноманітних філософських підходів, які спрямовують процеси прийняття рішень, коли моральні принципи є або нечіткими, або суперечливими. Інтеграція цих міждисциплінарних знань дозволяє отримати нюансоване розуміння того, як різні когнітивні, емоційні та соціальні фактори взаємодіють між собою та впливають на моральні вибори у контекстах, які часто є неоднозначними та наповненими невизначеністю. Результати підкреслюють складність морального пізнання, що свідчить про те, що ефективне прийняття моральних рішень потребує збалансованого врахування як когнітивних стратегій, так і емоційних реакцій, особливо в ситуаціях, коли результати є невизначеними, а етичний шлях не є чітко визначеним. Крім того, ці висновки мають важливе значення для практичного застосування у таких сферах, як етика, прийняття рішень, психологія та державна політика, де розуміння взаємодії між когнітивними та емоційними факторами може підвищити якість рішень, що приймаються в умовах моральних викликів.
Ключові слова: *прийняття моральних рішень, невизначеність, вентромедіальна префронтальна кора, передня поясна кора, мигдалеподібне тіло, когнітивні стилі, атрибуційні стилі, моральна невизначеність.*

Introduction. Moral decision-making is a complex and multifaceted process that involves the integration of cognitive, emotional, and social factors. The ability to make moral choices is essential in both personal and societal contexts, influencing outcomes in areas ranging from healthcare to business ethics. However, these decisions are often made under conditions of uncertainty, where the correct course of action is not clear-cut, and individuals must navigate conflicting values and incomplete information.

Recent advances in cognitive neuroscience have provided deeper insights into the brain mechanisms underlying moral decision-making, particularly the roles of the prefrontal cortex (PFC), ventromedial prefrontal cortex (vmPFC), anterior cingulate cortex (ACC), and amygdala. These regions are critical for integrating emotional and cognitive information, managing conflict, and evaluating potential outcomes. For instance, research by Hogan, Galaro, and Chib [8] has highlighted the vmPFC's role in subjective

valuation during decision-making, while the ACC has been shown to be crucial in resolving choice difficulties.

Cognitive styles, such as analytic versus holistic thinking and intuitive versus deliberative processing, further complicate this process. These styles influence how individuals perceive and process information, leading to different approaches to moral dilemmas. San Martin, Schug, and Maddux [16] demonstrated that cultural factors can shape cognitive styles, affecting how people approach moral decisions. Additionally, Rubin et al. [15] found that intuitive decision-making can be as effective as deliberative processing in aligning with individuals' true preferences, particularly in emotionally charged situations like end-of-life care.

Attributional styles also play a significant role in moral decision-making by shaping how individuals assign responsibility and causality in morally ambiguous situations. Toti, Diallo, and Huaman-Ramirez [19] explored the impact of internal versus external attribution on ethical behavior, finding that individuals with a strong internal locus of control are more likely to take personal responsibility for their actions. In contrast, Haggag et al. [6] showed that attribution biases could lead to flawed judgments, particularly when transient states are misattributed to stable qualities.

Moreover, the challenges of moral decision-making are exacerbated by uncertainty, a condition where individuals must make choices without complete knowledge of the consequences. MacAskill, Bykvist, and Ord [12] addressed this issue by proposing a framework for making decisions under moral uncertainty, emphasizing the need for norms that account for varying degrees of moral credence. This perspective is crucial for understanding how individuals can navigate moral dilemmas when the correct action is not clearly defined.

Purpose of the Study. The purpose of this study is to explore the cognitive, neural, and attributional mechanisms underlying moral decision-making under uncertainty. By integrating insights from cognitive neuroscience, psychology, and moral philosophy, this research aims to provide a comprehensive understanding of how different cognitive styles and attributional biases influence the moral decision-making process. Additionally, the study seeks to examine how individuals navigate moral uncertainty and the role that brain regions such as the vmPFC, ACC, and amygdala play in this process.

Through this study, we aim to contribute to the broader understanding of moral cognition and provide insights that can inform practical applications in fields such as ethics, decision-making, and public policy.

Literature Review

3.1. Brain Centres and Moral Decision-Making

Moral decision-making, particularly under conditions of uncertainty, is significantly influenced by the activity of various brain centres. Research has shown that different individuals employ distinct moral strategies, such as guilt aversion and inequity aversion, which are underpinned by specific neural substrates. van Baar, Chang, and Sanfey [20] investigated these strategies within the context of a modified Trust Game, revealing that the ventromedial prefrontal cortex (vmPFC) and anterior cingulate cortex (ACC) are crucial in differentiating between guilt and inequity aversion. Furthermore, the study identified a novel strategy termed "moral opportunism," wherein individuals switch between these moral strategies, with corresponding changes in neural activation patterns, underscoring the vmPFC's role in adaptive moral decision-making.

In a complementary study, Zhang and Gläscher [21] explored the neural mechanisms underlying social influences on decision-making. They demonstrated that the ventromedial prefrontal cortex and anterior cingulate cortex play dissociable yet interacting roles in processing direct and vicarious valuation during decision-making. These findings suggest that the vmPFC is not only involved in processing personal moral decisions but also in integrating social information, highlighting its importance in contexts where social and moral factors intertwine.

Additionally, the role of emotion in moral decision-making is crucial, as evidenced by Alsharif, Salleh, and Baharun's [2] review of the neural correlates of emotion. They emphasized the amygdala and vmPFC's central roles in processing emotions, which directly influence decision-making processes. Their findings reinforce the idea that the vmPFC is integral to managing emotional responses to risk and reward, thereby impacting moral judgments under uncertainty.

Finally, Si et al. [17] provided insight into the different brain networks activated during various decision-making stages. Their study using EEG and TMS demonstrated that decisions to accept or reject unfair offers engage distinct neural circuits, with acceptance associated with a bottom-up flow of information from the visual cortex to the frontal areas, and rejection characterized by a top-down flow from the frontal cortex to other regions. This distinction further illustrates the complexity of brain mechanisms involved in moral decision-making, with the frontal cortex playing a pivotal role in guiding decisions, especially under morally ambiguous circumstances.

The prefrontal cortex (PFC), particularly the ventromedial prefrontal cortex (vmPFC) and anterior cingulate cortex (ACC), plays a critical role in moral decision-making by integrating emotional and cognitive processes that guide behavior under uncertainty. Research has consistently shown that the vmPFC is crucial for

encoding the subjective valuation of decisions, particularly those involving moral or ethical considerations. For example, Hogan, Galaro, and Chib [8] demonstrated that the vmPFC is integral in the subjective valuation of prospective effort, independent of reward and choice difficulty, suggesting that this region is central to assessing the personal costs associated with moral decisions.

Furthermore, the ACC has been implicated in managing the cognitive aspects of moral decision-making, particularly in situations where there is a conflict or difficulty in making choices. Hogan et al. [8] found that ACC activity correlates with choice difficulty, highlighting its role in evaluating complex moral dilemmas where conflicting values or outcomes are at stake. This finding aligns with the broader view that the ACC is involved in error detection and conflict monitoring, which are essential processes when navigating morally ambiguous situations.

The amygdala, another critical brain region, is heavily involved in emotional processing and has been shown to influence morally relevant choices. Piretti et al. [14] explored the role of the amygdala in processing self-conscious emotions such as shame and guilt. Their study on a patient with bilateral amygdala damage revealed significant impairments in the recognition of social violations and the generation of appropriate emotional responses, underscoring the amygdala's importance in detecting socially salient cues that are integral to moral decision-making. The findings suggest that the amygdala plays a vital role in resolving ambiguity and uncertainty, which are common in moral judgments.

Additionally, the orbitofrontal cortex (OFC) has been identified as a key region in evaluating outcomes and making decisions under uncertainty. Klein-Fl gge, Bongioanni, and Rushworth [10] reviewed evidence from studies on humans and animals, demonstrating that the OFC is involved in representing the value of different choices and adapting behavior based on changing environmental contexts. The OFC's involvement in flexible decision-making processes indicates its importance in scenarios where moral decisions must be adjusted based on new information or shifting circumstances.

Finally, the interplay between these brain regions is crucial for making moral decisions under uncertainty. Liu, Yuan, Luo, and Cui [11] highlighted the functional connectivity between the medial prefrontal cortex (mPFC) and other brain areas, such as the orbital mPFC and the anterior cingulate, in predicting moral bias in economic valuation. Their findings suggest that the integrated activity of these regions supports the processing of complex moral information, influencing how individuals weigh moral and economic considerations when making decisions.

3.2. Cognitive Styles

Cognitive styles refer to the characteristic ways in which individuals perceive, think, and solve problems. These styles are not uniform across all individuals; instead, they vary significantly, influencing how people process information and make decisions. Cognitive styles are generally categorized into different dimensions, such as analytic versus holistic thinking and intuitive versus deliberative processing.

Analytic thinking is typically characterized by a focus on individual components, logic, and systematic problem-solving. In contrast, holistic thinking involves perceiving overall patterns and relationships among components within a broader context. San Martin, Schug, and Maddux [16] explored the cultural basis of these cognitive styles, showing that relational mobility–a socio-ecological factor–significantly influences whether individuals adopt an analytic or holistic cognitive style. Their study found that individuals in low relational mobility cultures (e.g., Japan) tend to adopt more holistic thinking, focusing on contextual and relational aspects, whereas those in high relational mobility cultures (e.g., the United States) are more likely to exhibit analytic thinking, emphasizing object-based and logical analysis.

The distinction between intuitive and deliberative processing is another critical dimension of cognitive styles relevant to decision-making. Intuitive processing is fast, automatic, and often based on heuristics or gut feelings, whereas deliberative processing is slower, more effortful, and rule-based. Rubin et al. [15] conducted a randomized clinical trial to examine the impact of these cognitive styles on decision-making in high-stakes situations, such as end-of-life care decisions. Their findings indicated that although deliberative processing is commonly assumed to improve decision quality by encouraging thorough consideration of all relevant factors, intuitive decisions were often more closely aligned with the patients' underlying health state valuations. This suggests that intuitive processing may, in some cases, lead to decisions that better reflect an individual's true preferences, particularly in complex and emotionally charged situations.

Moreover, the integration of big data analytics into decision-making processes highlights the importance of balancing analytic and intuitive cognitive styles. Akter et al. [1] proposed a six-step framework for analytics-driven decision-making, emphasizing the need for iterative and interdependent processes that blend data-driven insights with intuitive judgment. Their study underscores the practical relevance of combining these cognitive styles, particularly in service systems where decisions must be both data-informed and contextually relevant.

Lastly, Kemler [9] provided insights into the development of cognitive styles, particularly the

shift from holistic to analytic thinking as individuals mature. This transition reflects an increased ability to differentiate and categorize information, moving from a more intuitive and holistic approach to a more deliberate and analytic one. The developmental perspective offered by Kemler is crucial in understanding how cognitive styles evolve over time and how these changes impact decision-making strategies.

3.3. Attributional Styles

Attributional styles refer to how individuals explain the causes of events, particularly in moral contexts where decisions often involve judgments about responsibility and blame. These styles are critical in understanding how people make sense of their actions and the actions of others, especially when faced with morally ambiguous situations.

One key dimension of attributional style is the distinction between internal and external attribution. Internal attribution involves attributing the cause of an event to factors within the individual, such as their character or intentions. In contrast, external attribution ascribes the cause to situational factors outside the individual's control. Toti, Diallo, and Huaman-Ramirez [19] explored the role of internal locus of control (iLOC) in ethical decision-making, which is closely related to internal attribution. They found that individuals with a stronger iLOC are more likely to take personal responsibility for their actions, leading to more consistent ethical judgments and behaviors. This suggests that internal attribution can enhance moral responsibility, particularly when individuals perceive themselves as having control over their actions.

Another important dimension is stable versus unstable attribution. Stable attributions refer to causes that are perceived as consistent and unchanging over time, while unstable attributions involve causes that can vary. Haggag et al. [6] examined how attribution bias can influence consumer choices, demonstrating that people often misattribute the effects of transient states (e.g., hunger or weather) to the stable qualities of a product or experience. This misattribution can lead to flawed decision-making, as individuals may wrongly perceive temporary conditions as permanent characteristics. In moral contexts, this could manifest as individuals mistakenly attributing a one-time action to a person's inherent character, thereby affecting judgments of moral responsibility.

Attributional styles significantly impact moral decision-making, particularly in situations where responsibility is ambiguous. For example, in morally complex scenarios, individuals with a propensity for external attribution might deflect responsibility by blaming situational factors, leading to less accountability for unethical actions. Conversely, those with an internal attribution style might take greater personal responsibility, even in situations where external factors play a significant role.

Moreover, attributional styles influence decision-making processes in morally ambiguous situations by shaping how responsibility is perceived. Gambetti and Giusberti [5] found that personality traits like anxiety and self-control, which influence attributional styles, also affect financial decision-making. Anxious individuals, who may be prone to external and unstable attributions, tend to avoid risks and perceive lower control over outcomes, which can lead to conservative decisions. In contrast, those with higher self-control, associated with internal and stable attributions, are more likely to engage in rational decision-making and assume responsibility for the outcomes.

In organizational contexts, management styles can also reflect underlying attributional styles, influencing how decisions are made and justified. Sulich, Sołoducho-Pelc, and Ferasso [18] discussed how pro-ecological management styles are shaped by decisions that reflect both internal and external attributions. For instance, leaders who attribute environmental outcomes to internal corporate responsibility may adopt more sustainable practices, while those who attribute these outcomes to external market pressures might adopt less proactive strategies. This interplay between attributional styles and decision-making underscores the importance of understanding how attributions influence moral and ethical judgments in both individual and organizational settings.

Discussion. The interplay between cognitive styles, attributional styles, and the underlying neural mechanisms significantly shapes how individuals approach moral decision-making, particularly under conditions of uncertainty. This discussion integrates insights from various studies to highlight the complexities involved in making moral choices when faced with uncertain outcomes.

Moral decision-making is inherently complex, often requiring individuals to balance competing values and navigate ambiguous situations. The brain regions involved in this process, particularly the prefrontal cortex (PFC), ventromedial prefrontal cortex (vmPFC), anterior cingulate cortex (ACC), and amygdala, play crucial roles in integrating emotional and cognitive information. For instance, Hogan et al. [8] demonstrated that the vmPFC is essential in subjective valuation, especially when decisions involve prospective effort, indicating its broader role in moral judgments that require weighing potential costs and benefits. Similarly, the ACC's involvement in managing choice difficulty, as highlighted by the same study, underscores its importance in situations where moral decisions are not

straightforward, often necessitating cognitive control and conflict monitoring.

Attributional styles further complicate moral decision-making by influencing how individuals assign responsibility for outcomes. Toti, Diallo, and Huaman-Ramirez [19] emphasized the role of internal versus external attribution in ethical decision-making, with internal attributions linked to a greater sense of personal responsibility. This is particularly relevant in moral contexts where the perceived locus of control can dictate whether individuals feel accountable for their actions or deflect responsibility onto external factors. Haggag et al. [6] explored attribution bias in consumer choice, revealing how individuals often misattribute temporary states to stable qualities, leading to flawed judgments. This bias can similarly affect moral decisions, where transient emotions or situational factors are wrongly ascribed to an individual's character or intentions, complicating the assessment of moral responsibility.

Cognitive styles, such as analytic versus holistic thinking and intuitive versus deliberative processing, also play a critical role in how moral decisions are approached. San Martin, Schug, and Maddux [16] found that cultural contexts significantly influence whether individuals adopt an analytic or holistic cognitive style, which in turn affects how they process moral information. For instance, individuals in low relational mobility cultures are more likely to engage in holistic thinking, considering broader contextual factors, which might lead to different moral conclusions than those reached through a more analytic approach that focuses on specific details. Rubin et al. [15] further demonstrated that intuitive decisions, often made under cognitive load, can be as effective or even more aligned with individuals' true preferences than deliberative decisions, particularly in high-stakes moral contexts such as end-of-life care.

The challenges of moral decision-making under uncertainty are compounded by the difficulty of predicting outcomes and the potential moral consequences of those outcomes. MacAskill, Bykvist, and Ord [12] discuss the concept of moral uncertainty and the need for distinctive norms to guide decision-making when individuals are uncertain about the correct moral action. Their information-sensitive approach to decision-making under moral uncertainty suggests that the process should depend on the degree to which the relevant moral theories are comparable. This perspective is critical in understanding how individuals navigate moral choices when they are uncertain about the underlying moral principles, a common scenario in real-world ethical dilemmas.

FeldmanHall and Shenhav [4] provide a framework for understanding how social uncertainty influences decision-making, particularly in social contexts where the thoughts and intentions of others are hidden. Their model suggests that individuals first rely on automatic inferences and then engage in more deliberate processing as they attempt to reduce uncertainty. This process mirrors the cognitive styles discussed earlier, where the balance between intuitive and deliberative thinking is crucial for managing the complexity of moral decisions in uncertain social environments.

Moreover, Packard and Clark [13] distinguish between mitigable and immitigable uncertainties, arguing that the choice between predictive and adaptive strategies in decision-making depends on the extent to which uncertainty can be mitigated. This distinction is relevant in moral decision-making, where some uncertainties (such as those related to outcomes) may be reducible through additional information, while others (such as those related to fundamental moral principles) may be inherent and unavoidable.

In conclusion, moral decision-making under uncertainty is a multifaceted process influenced by neural mechanisms, cognitive and attributional styles, and the nature of the uncertainty involved. The integration of these factors underscores the need for a nuanced approach to understanding how individuals navigate moral choices in the face of uncertainty, with implications for both theoretical frameworks and practical applications in fields ranging from ethics to organizational behavior.

Conclusion. This study has examined the intricate processes involved in moral decision-making under uncertainty, drawing on evidence from cognitive neuroscience, psychology, and moral philosophy. The findings underscore the significant roles played by key brain regions, such as the ventromedial prefrontal cortex (vmPFC), anterior cingulate cortex (ACC), and amygdala, in integrating cognitive and emotional information essential for navigating morally ambiguous situations. The vmPFC, in particular, has been highlighted as a critical area for subjective valuation and decision-making, while the ACC's involvement in conflict resolution and the amygdala's role in emotional processing further emphasize the complex neural underpinnings of moral choices.

Cognitive styles, including analytic versus holistic thinking and intuitive versus deliberative processing, were shown to significantly influence how individuals approach moral dilemmas. The variability in these cognitive styles, shaped by cultural and situational factors, suggests that moral decision-making is not a one-size-fits-all process but rather a dynamic interplay of personal, cultural, and contextual influences. The study by San Martin et al. [16] highlights the impact of relational mobility on cognitive style, demonstrating the importance of considering socio-cultural factors in understanding moral cognition.

Attributional styles also play a crucial role in moral decision-making, particularly in how individuals assign responsibility and causality in morally charged situations. The research findings suggest that internal versus external and stable versus unstable attributions significantly affect how responsibility is perceived and how moral decisions are made. Individuals with a strong internal locus of control, for example, are more likely to take personal responsibility for their actions, which can lead to more consistent ethical behavior.

Moreover, the study has explored the challenges posed by moral uncertainty, where individuals must make decisions without complete knowledge of the consequences or without clear moral guidelines. The work of MacAskill, Bykvist, and Ord [12] provided a framework for understanding how to navigate moral uncertainty, emphasizing the need for norms that account for varying degrees of moral credence. This approach is particularly relevant in real-world ethical dilemmas, where the correct course of action is often not immediately apparent.

In conclusion, this study has provided a comprehensive examination of the factors that influence moral decision-making under uncertainty. By integrating neural, cognitive, and attributional perspectives, the research offers valuable insights into the complexities of moral cognition and highlights the importance of understanding the diverse factors that shape moral judgments. These findings have significant implications for fields such as ethics, decision-making, and public policy, suggesting that interventions and strategies aimed at improving moral decision-making should consider the multifaceted nature of moral cognition. Future research should continue to explore these dynamics, particularly in applied settings, to better understand how individuals can be supported in making ethical decisions in uncertain and complex environments.

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