Rational Decision-Making Under Incomplete Information: The Construction and Application Analysis of a Hierarchical Information Acquisition Model

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Abstract

This paper explores the rational decision-making process of individuals in situations of incomplete and uncertain information, and proposes a hierarchical model of information importance. By analyzing the common behavior of jaywalking in daily life, the paper demonstrates how individuals, constrained by limited time and cognitive resources, make rational choices by weighing costs and benefits. Although jaywalking may appear "irrational," decision-makers often make reasonable assessments based on available information and context, particularly under time pressure or other external stresses. The paper further examines how information asymmetry can lead to decision biases, especially when information is insufficient or when its dynamic changes are difficult to predict, potentially resulting in outcomes that deviate from expectations.

Additionally, the paper analyzes information acquisition behaviors during the Cold War standoff between the U.S. and the Soviet Union, as well as in civil aviation navigation systems, to explore how decision-makers in high-stakes environments invest significant resources to obtain information and optimize decisions through a hierarchical information mechanism. In situations where the importance of information is extremely high, the balance between the accuracy and completeness of information, its correctability, and the cost of acquiring information becomes a key factor in determining decision quality. The paper innovatively proposes the concept of "predicting the importance of yet-to-be-acquired information" as crucial to whether decisions align with expectations. This research provides a new theoretical framework for understanding information acquisition and rational decision-making in complex contexts and offers practical insights into optimizing decisions in high-risk environments.

1.Introduction

In modern society, decision-making behavior is ubiquitous, and the acquisition and processing of information are critical components of the decision-making process. Whether in personal life, business management, or high-risk fields, individuals are often required to make decisions under conditions of incomplete or uncertain information. Traditional economics assumes that humans are fully rational and can make optimal choices based on all available information. However, Herbert A. Simon's theory of Bounded Rationality suggests that human cognitive abilities, time, and the costs of acquiring information are limited. Therefore, in complex decision-making situations, people cannot achieve perfect rationality and can only make "satisficing" decision [1]. This theory provides an important foundation for understanding decision-making behavior in the context of incomplete information.

However, despite Bounded Rationality theory and behavioral economics revealing biases and limitations in human decision-making, most existing research focuses on analyzing irrational behavior in situations of information asymmetry or information overload. There is relatively little attention paid to how individuals hierarchically acquire information based on its importance or how they balance the costs and benefits of information acquisition. For example, Prospect Theory in behavioral economics mainly focuses on decision-making biases in risk scenarios rather than the rational logic behind the information acquisition process [2]. As a result, existing research has not fully explained how individuals, under limited time and cognitive resources, rationally assess and acquire information to make decisions that align with their expectations.

The core research question of this paper is: How do individuals, under conditions of incomplete or uncertain information, rationally acquire and evaluate information in a hierarchical manner, and make decisions that meet expectations within limited time and cognitive resources?

The research objectives of this paper are to construct a hierarchical model of information importance to explain how, in high-stakes decision-making, individuals acquire information based on its importance and make rational decisions under limited time and cognitive resources. Specifically, this paper aims to:

- Analyze the trade-off between the costs and benefits of information acquisition, explaining how individuals decide how much information to acquire in different scenarios.
- Explore the logical process of rational decision-making under incomplete or inaccurate information, particularly how hierarchical information acquisition optimizes decision-making.
- Propose the concept of "predicting the importance of yet-to-be-acquired information," arguing that in situations where decision importance is extremely high, individuals should preemptively evaluate the importance of future potential information to optimize information acquisition behavior.

2.Literature Review

In the study of decision theory and behavioral science, the relationship between rationality and information acquisition has always been a central topic. Herbert A. Simon's theory of Bounded Rationality provides an important theoretical foundation for understanding human decision-making. Simon pointed out that individuals, when making decisions, are constrained by cognitive abilities, time, and the costs of acquiring information. As a result, they cannot achieve the "perfect rationality" defined by traditional economics and can only seek "satisficing" solutions rather than optimal ones [1]. This theory emphasizes how individuals make decisions using simplified strategies in the context of incomplete information, but it does not delve deeply into how information is acquired hierarchically based on its importance.

Behavioral economics further reveals the irrational characteristics of human decision-making. Daniel Kahneman and Amos Tversky's Prospect Theory shows that individuals exhibit systematic biases when facing risks, particularly in situations of information asymmetry or uncertainty, where people tend to overestimate losses and underestimate gains [2]. Although Prospect Theory provides a detailed analysis of irrational behavior in risk scenarios, it focuses more on the biases in decision outcomes rather than the rational logic behind the information acquisition process.

At the same time, information economics offers an important perspective for understanding the relationship between information asymmetry and decision-making. George Akerlof's study on the "market for lemons" demonstrates that information asymmetry can lead to market failure, as buyers and sellers have different perceptions of product quality [3]. This research highlights the impact of information asymmetry on market behavior but does not address how to rationally choose which information to acquire in situations of incomplete information.

In cognitive science, researchers focus on how humans process information in complex environments. Gerd Gigerenzer's theory of heuristics suggests that when faced with complex decisions, individuals often rely on simple heuristic rules rather than conducting comprehensive information gathering and analysis [4]. While such heuristic strategies can effectively reduce decision-making costs in some cases, they can also lead to systematic biases. Although Gigerenzer's research sheds light on decision-making mechanisms under incomplete information, it does not systematically discuss how cognitive resources are allocated based on the importance of information.

Additionally, research on information processing and decision fatigue provides new insights into the costs of information acquisition. Studies show that when individuals face information overload, their cognitive resources are limited, often leading to "decision fatigue," which negatively affects decision quality [5]. However, this line of research mainly focuses on the negative impacts of information overload, with less emphasis on how to rationally decide which information to acquire when information is insufficient.

While existing studies offer a rich theoretical foundation for understanding decision-making under conditions of incomplete or asymmetric information, they primarily focus on two areas: first, revealing irrational behaviors under information asymmetry or overload, and second, discussing how

bounded rationality uses heuristic strategies to cope with complex decision-making situations. However, there has been relatively little exploration of how information is acquired hierarchically based on its importance, and there is a lack of systematic analysis of the trade-offs between the costs and benefits of information acquisition.

The innovation of this paper lies in proposing a hierarchical model of information importance, which explains how individuals, when faced with incomplete or uncertain information, acquire information hierarchically based on its importance and make rational decisions under limited time and cognitive resources. Specifically, this paper proposes the following:

- Mechanism of Hierarchical Information Acquisition: The ability to acquire information hierarchically based on its importance is key to rational decision-making. Through case studies (such as RNP navigation in civil aviation), this paper demonstrates how information can be acquired hierarchically based on its importance to ensure safety and accuracy in decision-making. This perspective differs from traditional heuristic decision-making theories, which focus more on simplifying the decision process rather than on the hierarchical acquisition of information based on its importance.

- Trade-off Between Costs and Benefits of Information Acquisition: This paper further explores how individuals rationally evaluate and acquire information under limited time and cognitive resources. Unlike Prospect Theory or Bounded Rationality Theory, this paper not only focuses on biases in decision outcomes but also examines the rational logic in the information acquisition process—how individuals decide how much information to acquire based on its importance.

- Introduction of Information Prediction Capability: This paper introduces the concept of "predicting the importance of yet-to-be-acquired information," emphasizing that in certain high-risk scenarios, rational decision-makers should not only assess the accuracy of current information but also predict which future information will be important and at what cost it can be acquired. This innovative perspective has not been fully discussed in existing studies on Bounded Rationality and information economics.

Through these innovations, this paper not only extends the application of Bounded Rationality Theory but also provides a new theoretical framework for understanding how individuals acquire information in complex decision-making contexts. The research in this paper not only helps explain decision-making behavior in everyday life (such as the rational analysis of jaywalking) but also provides theoretical support for information acquisition strategies in high-risk environments.

3.Theoretical Framework

The essence of rational decision-making lies in logical consistency rather than achieving an absolutely optimal outcome. In the framework proposed in this paper, rational decision-making is based on the following four premises:

1. The goal of rationality is not to achieve perfect decisions or actions, but to ensure that outcomes align with expectations.
2. Information gaps are the reasons why decisions or actions may fail to meet expectations.
3. When individuals have sufficient and accurate information, the decisions or actions they make will always meet expectations.
4. Human time and cognitive resources are limited, so individuals must choose which information to acquire and at what cost.

An information gap is one of the main causes of decision bias. An information gap refers to the incompleteness or inaccuracy of the information available to the decision-maker, which leads to outcomes that deviate from expectations.

Under the constraints of limited time and cognitive resources, decision-makers must weigh the costs and benefits of acquiring information. Acquiring more information typically requires more time, effort, or resources, but the additional information can also lead to better decision outcomes. Therefore, rational decision-makers need to determine how much information to acquire based on its importance, optimizing the cost-benefit ratio of the decision.

To better explain how individuals make rational decisions in situations of incomplete information, this paper proposes a hierarchical model of important information acquisition. The model assumes that during the decision-making process, individuals acquire information hierarchically based on its importance and make optimal rational choices by balancing the costs and benefits of acquiring information.

The hierarchical model of information importance consists of the following four levels:

1. Basic Information Acquisition: This is the most fundamental information that a decision-maker needs to acquire before making any decision. This information is typically a prerequisite for the decision; without it, the decision cannot proceed.

2. Verification of Information Accuracy and Completeness: After acquiring the basic information, the decision-maker needs to continue gathering information to verify the accuracy and completeness of the existing information.

3. Information Correction: When it is found that the existing information is inaccurate or incomplete, the decision-maker must have the ability to correct their understanding using other accurate information.

4. Information Prediction: In high-stakes decisions, the decision-maker also needs to predict the importance of information that may be required in the future, guiding them on how much effort and resources should be expended to acquire further information.

Through this hierarchical model, the paper proposes strategies for acquiring information hierarchically based on its importance in different scenarios.

4.Case Analysis

1. Deconstructing the Rational Decision-Making Process in Jaywalking

Let’s take the common phenomenon of jaywalking as an example. Most people choose not to jaywalk because, after a rational assessment, they conclude that the time saved by crossing the street against the light is not worth the potential risk to their life and safety. This choice reflects a typical risk–reward trade–off in everyday life: the cost of obeying traffic rules (waiting for the light) is relatively low, whereas the potential safety risk of jaywalking is disproportionately high.

However, a minority of individuals may choose to jaywalk under specific circumstances. These individuals do not completely ignore the risks but rather make a rational assessment based on their situation. For instance, a food delivery worker might feel pressured by the risk of incurring a late penalty and thus view the time cost of waiting for the light as too high. Others, due to bad habits or being in a rush, may perceive the potential time savings from jaywalking as outweighing the possible risks. In this case, the trade–off between costs and benefits becomes the core of their decision–making process.

When deciding to jaywalk, most people will put down their phones and focus on observing the traffic conditions to gather the necessary environmental information. This behavior indicates that, although they have chosen to take a risk, they are still attempting to reduce that risk by acquiring more information. The potential benefit of gathering traffic information (avoiding an accident) far outweighs the short–term entertainment value of continuing to use their phone. As a result, decision–makers temporarily shift their attention from other activities to the traffic situation, concentrating their efforts to ensure they can cross the street safely.

This information–gathering behavior demonstrates how individuals adjust their information acquisition strategy based on the importance of the decision (in this case, life–threatening risks). Even when they decide to engage in seemingly "irrational" behavior (jaywalking), they still attempt to mitigate the risk by incurring a small cost (pausing entertainment) to obtain more traffic information, hoping to reduce the risk in a critical, life–related decision.

Although in most cases jaywalking does not result in accidents, there are situations where accidents still occur. This phenomenon can be explained by the presence of information gaps, where the decision–maker does not have enough or accurate information when making the decision. This can be observed in two main ways:

> Insufficient Information Acquisition: Pedestrians or drivers may fail to fully gather all relevant information when observing traffic conditions. For example, they may focus only on the vehicles in front of them and neglect traffic coming from the side or rear. This insufficient information acquisition may lead them to underestimate the risks of jaywalking, resulting in a poor decision. The reason for this insufficient information is often that the decision–maker has misjudged the importance of the yet–to–be–acquired information, believing that acquiring such information (e.g., turning their head to check for oncoming vehicles from the side) is unnecessary.

Unpredictability of Dynamic Information: Even if the decision-maker has gathered some information, certain critical pieces of information (such as changes in the speed or direction of vehicles) may change rapidly and exceed their predictive abilities. Since the current traffic system is not designed to provide real-time information specifically for "safely jaywalking," pedestrians or drivers cannot fully grasp all dynamic changes in real-time. This means that, although they may have gathered some traffic information, the dynamic complexity of the traffic environment still presents unpredictable risks.

Changes in vehicle direction and speed are typically difficult to predict because the current traffic system does not include mechanisms designed to provide real-time information for "safe jaywalking." In other words, the system does not consider it necessary to install sensors for pedestrians or vehicles to ensure safe jaywalking (i.e., the importance of acquiring such information is deemed insufficient).

Summary of the Case:
1) Insufficient or inaccurate information can lead to decisions or actions that do not meet expectations.
2) When the importance (criticality) of a decision or action increases, individuals will invest more resources to acquire information, especially when the cost of doing so is not significantly high while the benefits increase substantially.
3) Human time and cognitive resources are limited, making it impossible to acquire all information fully. Individuals must choose which information to acquire and at what cost.
4) The failure to accurately predict the importance of future information can easily lead to decisions or actions that do not meet expectations, especially when information is incomplete or incorrect.
5) When the cost of acquiring information is extremely high, and the decision or action itself is not critical (or can be bypassed through low-cost alternatives), individuals generally forgo acquiring information at high costs (e.g., the current system does not consider installing sensors for pedestrians or vehicles to ensure safe jaywalking as a necessary measure).

2. High Information Importance and Enormous Information Acquisition Costs During the U.S.-Soviet Cold War

The Cold War between the U.S. and the Soviet Union was one of the most tense confrontations in human history. Over the course of several decades, both sides competed not only in military, economic, and political spheres but also invested enormous resources in information acquisition. Since the Cold War was fundamentally a nuclear deterrence standoff between two superpowers, any information gap or misjudgment could have led to catastrophic consequences. Therefore, the importance of information during the Cold War was extremely high, and both sides spared no expense in acquiring, analyzing, and verifying critical information to ensure the accuracy and safety of their decisions.

Insufficient or incorrect information acquisition often led to incorrect judgments about the importance of future information, which in turn resulted in continued insufficient or erroneous

acquisition of highly important information, ultimately causing decisions or actions to deviate from their intended objectives. Initial information gaps or errors could be amplified into undesirable final outcomes. This phenomenon can be explained as a consequence of misjudging the "completeness and accuracy of existing information," which is critical in determining the importance of further information acquisition.

Summary of the Case:
6) When the cost of acquiring information is extremely high, and the decision or action is critically important, information is usually acquired regardless of cost.
7) The "assessment of the completeness and accuracy of information" is crucial in determining whether decisions align with expectations.

3. Hierarchical Information Acquisition in High-Importance Information Environments—RNP Navigation in Civil Aviation

The navigation of civil aircraft is critical to the safety of every passenger. In situations where ground navigation stations are unavailable or the terrain is extremely complex, aircraft may rely solely on satellite positioning. In such cases, satellites become the only source of navigation data, making the reliability of satellite navigation signals crucial.

In Required Navigation Performance (RNP) systems, the first priority is to ensure the ability to detect errors in satellite data. Secondly, if an error is detected in the data from one satellite, it must be immediately replaced by data from a functioning satellite (the system must have the ability to resolve the issue mid-flight). Lastly, before takeoff, there must be a prediction of potential satellite unavailability.

An aircraft requires at least four satellites for accurate positioning. However, with only four satellites, it is impossible to identify which satellite’s data is incorrect. When a fifth satellite is added, it becomes possible to detect errors in the existing data, but not to resolve them. With a sixth satellite, the faulty satellite data can be replaced, thereby resolving the error.

RAIM (Receiver Autonomous Integrity Monitoring) prediction is a technique used before takeoff to predict the integrity and accuracy of GPS signals. RAIM prediction calculations consider factors such as GPS satellite ephemeris, satellite fault notifications, and airport cut-off elevation angles. With RAIM prediction, the likelihood of encountering unreliable GPS signals during flight can be minimized.

In this case:
- The fifth satellite serves to detect errors, providing the capability to verify the "correctness of existing information."
- The sixth satellite serves to correct errors, providing the ability to adjust decisions or actions after detecting that "existing information is incorrect."
- RAIM prediction can be seen as the capability to "predict the importance of yet-to-be-acquired information."

Summary of the Case:

8) In situations where decisions or actions are critically important (high-information-importance scenarios), hierarchical information acquisition is possible.

9) Hierarchical information acquisition consists of four levels:

- Sufficient information for decision-making
- Sufficient information to verify the completeness and correctness of the information
- Sufficient information to correct deficiencies in the completeness and correctness of the information
- The ability to "predict the importance of yet-to-be-acquired information."

<u>According to the framework of this paper, the ability to predict the importance of yet-to-be-acquired information is the most critical factor in determining whether decisions or actions will meet expectations.</u>

5.Conclusion

1.The accuracy and completeness of information are directly related to whether decisions will deviate from expectations.

2.Never underestimate anyone. Human behavior is not as "irrational" as it may appear on the surface; rather, it is a rational choice based on limited information, time, and cognitive resources.

3.When the importance of information becomes extremely high, increasing the amount of information acquired (and thus the cost of acquisition) becomes unavoidable. How much information is enough? This can be determined through hierarchical information acquisition based on the level of importance:

1) Sufficient information to make a decision;
2) Sufficient information to identify issues with the accuracy or completeness of the information;
3) Sufficient information to replace incorrect information or fill information gaps when issues with accuracy or completeness are detected;
4) If the decision is critically important, one should possess the ability to "predict the importance of yet-to-be-acquired information" to guide how much further information should be acquired and at what cost

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